Economic Development and the Business Cycle: Applications to Emerging Markets and the Great Depression

Dissertation

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Chapter 1

Introduction

This thesis investigates the driving forces behind economic development and the business cycle using methods of modern macroeconomics. A thorough analysis of the nature of short–term fluctuations yields, not only during times of crisis, important ramifications for policy makers. Furthermore, understanding the determinants of economic development delivers important insights. This is particularly meaningful today, in the aftermath of a global economic and financial crisis, while at the same time Emerging Market Economies (EMEs) have been growing rapidly and turned out to be a major driver of the global economy during the past years. As a result, this thesis focuses on the analysis of economies at different stages of development during different historical periods. While Chapter 2 is devoted to aspects of economic development and the business cycle in Emerging Market Economies (EMEs), Chapters 3 and 4 investigate the cases of Switzerland and Germany during the Great Depression by analyzing their economic slumps and its peculiarities individually. For this purpose, I apply Dynamic Stochastic General Equilibrium (DSGE) models of various types. While the models used in Chapters 2 and 4 belong to the class of small open economy Real Business Cycle (RBC) models, Chapter 3 uses a New Open Economy Macroeconomics (NOEM) framework, which corresponds to a New Keynesian model with small open economy characteristics. All essays include an empirical part, in which I apply modern time series techniques. The models are estimated through Bayesian approaches. The structural orientation of this thesis allows for a detailed analysis of the economies considered. The following chapters emphasize that the current level of economic and financial development, as well as the historical and political circumstances crucially affect the future economic development and the effectiveness of macroeconomic policy interventions.

Chapter 2 **"Business Cycles in Emerging Markets: the Role of Liability Dollarizaton and Valuation Effects"** is joint work with Stefan Notz. The purpose of this chapter is to investigate the importance of certain credit market imperfections in Emerging Markets. To this end, we develop a small open economy DSGE framework featuring both permanent and transitory productivity shocks, differentiated home and foreign goods, liability dollarization, and endogenous exchange rate movements. Furthermore, our model incorporates liability dollarization as a particular form of financial frictions in EMEs. We estimate our model using Bayesian techniques for a number of EMEs and our main findings are that (i) trend shocks are the main determinant of macroeconomic fluctuations, (ii) accounting for liability dollarization ameliorates the model fit, (iii) valuation effects on average stabilize changes in the net foreign asset position.

Chapter 3 **"A Small Open Economy in the Great Depression: the Case of Switzerland"** is joint work with Ulrich Woitek and Tobias Straumann. This part of the thesis investigates the causes of the slow recovery of the Swiss economy of the Great Depression in the 1930s. In historical accounts of the world economic crisis of the 1930s, Switzerland is known for its staunch defense of the gold standard and the rise of corporatist policies. Yet, so far, the literature has not discussed the implications of these two features. This paper tries to show how the combination of hard–currency policy and nominal rigidities introduced by corporatist policies proved to be fatal for growth. Estimating a New Keynesian small open economy model for the period 1926–1938, we show that the decision to participate in the Gold Bloc after 1933 at an overvalued currency can be identified as the main reason for the unusual long lasting recession and that price rigidities from 1931 to 1936 significantly slowed down the adjustment process.

Chapter 4 **"The Role of Labor Market Imperfections and Credit Constraints in the German Great Depression"** is based on my contribution to a joint project with Ulrich Woitek. The aim of this project is to analyze the determinants of the German business cycle for the period under analysis. For this purpose, I estimate a DSGE model with heterogeneous agents, open economy characteristics, and labor market inefficiencies. Allowing for three exogenous shocks (total factor productivity, government spending, and labor market inefficiencies), I find that labor market distortions played a major role in driving the German business cycle during the Interwar Period. Moreover, the analysis suggests a rather limited scope for expansionary government policies and that workers were hit more severely by the crisis than capitalists.

The following Sections 1.1, 1.2, and 1.3 provide more detailed reviews of the three essays.

1.1 Review of Chapter 2

We develop a DSGE model of a small open economy to study business cycle phenomena and the importance of financial frictions in EMEs. To this end, we allow for differentiated home and foreign goods as well as endogenous exchange rate movements. As in Aguiar and Gopinath (2007) and Chang and Fernández (2013), total factor productivity (TFP) contains both a transitory and permanent component. We also build on Schmitt-Grohé and Uribe (2003) and García-Cicco *et al.* (2010) by introducing a debt–elastic interest rate as a reduced form financial market imperfection. Moreover, our model features the phenomenon of *liability dollarization* (Reinhart *et al.*, 2014), which can be interpreted as a specific type of financial frictions in EMEs. Consequently, we account for the fact that emerging markets traditionally have had difficulties in borrowing in domestic currency on international capital markets (see Reinhart *et al.* 2003, Eichengreen and Hausmann 2005, and Lane and Shambaugh 2010).

The innovation of liability dollarization introduces the presence of valuation effects in our model in a straightforward manner. That is, valuation effects refer to changes in the net foreign asset position that do not arise from the current account but are due to fluctuations in exchange rates and asset prices. The size of these price effects in external balance sheets has been increasing over the last two decades. Consequently, this observation has attracted great academic attention in recent years. Thus, our work is also related to a currently active area of research, which highlights the importance of fluctuations in exchange rates and asset prices for a country's external balance sheet (Gourinchas and Rey 2007a, Gourinchas and Rey 2007b, Lane and Milesi-Ferretti 2007, and Gourinchas *et al.* 2010).

We estimate our model using Bayesian techniques for a number of emerging markets (Mexico, South Africa, and Turkey) and developed economies (Canada, Sweden, and Switzerland) and thereby control for potential heterogeneity across countries. Contrary to previous studies in this strand of the literature, we include a (vector–)autoregressive measurement error component to capture off–model dynamics along the lines of Ireland (2004). Regarding business cycles in emerging markets, our main findings are that (i) even though we incorporate financial frictions in the framework, trend shocks are the main driving force behind macroeconomic fluctuations, (ii) accounting for liability dollarization ameliorates the model fit and thus highlights the importance of modeling this financial market imperfection, and (iii) valuation effects on average stabilize changes in the net foreign asset position.

1.2 Review of Chapter 3

There are remarkable differences in the performance of small open European economies returning to gold in the Interwar Period. Whereas the Netherlands, Sweden, and Switzerland returned to the prewar parity in 1924/25, it took Denmark and Norway until 1926/28 because of significant trade deficits 1919/20 and weaknesses in the banking system. Strong trade links with the United Kingdom forced the Scandinavian countries off gold in 1931, while sufficient gold reserves allowed Belgium, the Netherlands, and Switzerland to stay on gold until 1935/36.

The gold standard mentality (Eichengreen and Temin, 2000; Mouré, 2002), i.e. the belief that a devaluation would lead to inflation and that the gold standard was the only reliable guarantee for prosperity and stability, led economies to stay on gold as long as possible – a decision which implied a lagged recovery from the Great Depression (e.g. Balderston, 2003; Feinstein *et al.*, 2008). As Straumann (2010, p. 129-142) shows, this was also the case for Switzerland.

We choose a New Keynesian small open economy model in the spirit of Galí and Monacelli (2005) to study the causes of the slow recovery of the Swiss economy of the Great Depression in the 1930s. In this vein, we allow for nominal rigidities in order to account for the extraordinarily sticky prices observed during this period.

We estimate the model using Bayesian techniques, thus going beyond the calibration exercises in Bordo *et al.* (2007) and Bordo and James (2007) for the Swiss economy. Furthermore, our data used for the estimation exercise represents a new monthly data set covering the period January 1926 – December 1938. Following Ireland (2004), the model incorporates a vector autoregressive measurement error component capturing the dynamics in the data which are not represented by the economic part.

Our results show that the decision to participate in the gold bloc after 1933 at an overvalued currency can be identified as the main reason for the unusual long lasting recession. Even the recovery of the world economy starting in 1932/1933, and thus a boost of foreign demand could not offset the negative effects resulting from disadvantageous terms of trade. A counterfactual experiment demonstrates that in case of leaving gold earlier (e.g. together with the UK in 1931), the Swiss economy would have recovered much faster, almost immediately reaching the pre–crisis output level.

Moreover, we find strong evidence for a large degree of cartelization in the Swiss economy during the Interwar Period in line with the qualitative evidence, which resulted in severe price rigidities. A counterfactual analysis predicts that a decrease in price rigidities would have lead to a weaker downturn and a faster recovery of the economy. In the literature, democratic corporatism is seen as an insurance tool for small open economies to cope with the exposure to shocks from abroad. The paper highlights the costs of corporatism during the recovery from the Great Depression.

1.3 Review of Chapter 4

We develop a DSGE model to study the driving forces of the German business cycle during the Interwar Period. In this vein, we contribute to ongoing discussions on the reasons of the German Great Depression. While on the one hand economic policy of austerity under the chancellorship of Heinrich Brüning (March 1930 to June 1932) is being blamed for deepening the depression and thus paving the path for the success of the NSDAP, Borchardt (1982) highlights internal and external constraints the economy was exposed to. Furthermore, he argues that the Germany economy was suffering structural problems while entering the Great Depression. In particular, he highlights the divergence of the evolution of the real wage and labor productivity in the 1920s, eventually resulting in excessive real wages. All these issues are still unresolved, and the project aims to contribute to this debate.

The point of departure is an extension of the model by Fisher and Hornstein (2002), thus modeling some of the key features of the German economy at the beginning of the 1930s. That is, we set up a DSGE model incorporating three sources of inefficiencies (total factor productivity, government expenditure, and a labor wedge). Furthermore, we make it an open economy, incorporate financial market frictions, and allow for heterogeneous agents (capitalists and workers). This last extension enables us to analyze the implications of shocks or policy choices and its impact on different agents. Moreover, the model can help to address the issue of the structural problems of the German labor market, measuring labor market frictions explicitly.

We estimate the model using Bayesian techniques using high quality monthly time series collected by the Institut für Konjunkturforschung in the 1920s and 1930s. Our results suggest that severe labor market frictions characterized the German business cycle during the Interwar years, which underpins the presence of structural problems in the economy. Also, variations in total factor productivity significantly contributed to the downturn. On the other hand, variations in government expenditure did rather play a minor role. Consequently, countercyclical demand side policies would not have sufficed to countervail the severe downturn.

Chapter 2

Business Cycles in Emerging Markets: the Role of Liability Dollarization and Valuation Effects

2.1 Introduction

Over the last twenty years, the world economy has witnessed a growing importance of Emerging Market Economies (EMEs). While their share of global output at purchasing power parity was about 30 percent in 1990, it has risen to more than 50 percent by 2013 according to the International Monetary Fund (IMF).[1] As a consequence, EMEs have increasingly influenced the global business cycle and are catching up to the rich world at a remarkable pace. What is striking, however, is that business cycles in these countries reveal noticeably different patterns compared to developed economies. This naturally raises the questions of why do we observe these discrepancies.

In recent years, considerable attention in research on international macroeconomics has been devoted to understanding business cycle fluctuations in EMEs. Many researchers have documented certain empirical regularities among these countries (see Neumeyer and Perri 2005, Aguiar and Gopinath 2007, and García-Cicco *et al.* 2010). First, EMEs are generally exposed to more severe business cycle

[1]See *The Economist*, article "When giants slow down", July 27th, 2013.

fluctuations than developed economies. Second, EMEs have strongly countercyclical net exports and their international capital inflows are subject to so–called "sudden stops" (see Calvo 1998, Calvo and Reinhart 2000, and Mendoza 2010). Third, consumption volatility exceeds income volatility.[2]

This paper develops a Dynamic Stochastic General Equilibrium (DSGE) model of a small open economy (SOE) to address these business cycle phenomena and the importance of credit market imperfections in EMEs. The basic structure of our framework goes back to the workhorse SOE real business cycle (RBC) model of Mendoza (1991). We build on Aguiar and Gopinath (2007) and introduce a permanent productivity shock in addition to a conventional transitory productivity shock in our theoretical economy. Moreover, we contribute to the existing RBC literature on emerging markets by featuring differentiated home and foreign goods as well as exogenous foreign demand shocks in our model. In this vein, we also incorporate endogenous real exchange rate fluctuations in our setup.

As Chari *et al.* (2007) point out, one can think of the non–stationary technology component as efficiency wedge which captures various forms of market distortions. Nevertheless, since our analysis aims at investigating the role of specific financial frictions in emerging market business cycles we also augment our framework along this dimension. In particular, similar to García-Cicco *et al.* (2010) we introduce credit market imperfections in form of a debt–elastic country premium on the interest rate. Indeed, this reduced form financial friction is a convenient way to account for a positive link between higher external indebtedness and borrowing costs, which seems to be empirically plausible (see Uribe and Yue 2006 or Arellano 2008).

More importantly, a major contribution of our work is that we also analyze the phenomenon of *liability dollarization* as a further form of financial frictions in our framework.[3] Emerging markets have traditionally depended heavily on external funds in form of short–term debt to finance their growth opportunities (see Kose and Prasad 2010). In contrast to advanced economies, however, international

[2]Another salient characteristic of emerging market business cycles is that real interest rates tend to be countercyclical, very volatile and lead the cycle (see Neumeyer and Perri 2005 and Uribe and Yue 2006). This feature, however, is not subject of the analysis in this paper.

[3]The term "liability dollarization" was coined by Calvo (2001).

capital market imperfections have impeded EMEs to issue debt denoted in their own currency. As a result, these countries have held the bulk of their external debt in major international currencies such as US dollars. The inability of borrowing abroad in domestic currency faced by emerging markets, which Eichengreen *et al.* (2005) refer to as the "Original Sin" phenomenon, is a well–known fact and has been documented in a number of previous studies (see Reinhart *et al.* 2003, Eichengreen and Hausmann 2005, and Lane and Shambaugh 2010).[4] Our paper does not investigate the reasons behind liability dollarization in emerging markets, but studies its implications. To this end, we extend our benchmark model and assume that the small open economy can only borrow in foreign currency.

In our empirical exercise, we apply a mixture of country–specific calibration and Bayesian estimation. Related studies have predominantly investigated particular emerging markets and partly tried to derive conclusions for EMEs in general. However, given the fact that EMEs share the aforementioned stylized business cycle features, we think it is crucial to expand the analysis to a broader selection of countries and thus also allow for potential heterogeneity. Therefore, we study the cases of Mexico, South Africa, and Turkey. Besides, we additionally estimate our benchmark model for a cohort of developed countries, namely Canada, Sweden, and Switzerland. This enables us to confront the results obtained for emerging and advanced economies.

To estimate our models, we take real time series data on output, consumption, interest rates, and exchange rates. A substantial contribution of our work is how we capture off–model dynamics in our estimation. In particular, we follow Sargent (1989) and Ireland (2004) by including a (vector–)autoregressive measurement error component. To our knowledge, this has not been done yet in this strand of the literature and goes beyond the procedures applied by existing studies (e.g. García-Cicco *et al.* 2010 or Chang and Fernández 2013).

Estimation results show that financial frictions are generally more pronounced in EMEs than in industrialized countries, which is in line with the conclusion of

[4] In recent years, several emerging markets have implemented various policies to tackle dollarization. The process of dedollarization is generally protracted and in most cases incomplete (see Kokenyne *et al.* 2010). While some countries have been successful, others have failed to achieve persistent dedollarization (see Reinhart *et al.* 2014). Nevertheless, our empirical analysis uses data from a period in which liability dollarization was a prevalent feature of external finances in EMEs.

García-Cicco *et al.* (2010). Besides, off–model dynamics appear to be of minor importance for the dynamics of macroeconomic aggregates in general. This result suggests that our model is capable of explaining a great deal of the variation in the data. Moreover, we show that for the group of EMEs, the model with liability dollarization by and large outperforms the benchmark setup in capturing the dynamics in the variables we use for estimation. This outcome provides a strong argument in favor of the introduction of liability dollarization in the model.

Our analysis suggests that the co–existence of financial market imperfections and trend shocks helps us to explain macroeconomic fluctuations in emerging markets. In EMEs, the transitory productivity process is the driving force behind output in the short–run, whereas non–stationary technology shocks determine income fluctuations in the long–run. Contrary to that, transitory productivity shocks determine output fluctuations over all horizons in developed economies. Hence, although we incorporate various financial frictions in our model, we still find support for the famous hypothesis by Aguiar and Gopinath (2007) that *"the cycle is the trend"* in emerging markets. That said, our findings contradict the conclusions of other studies, which argue that this notion rests upon the absence of certain market distortions. For instance, García-Cicco *et al.* (2010) and Chang and Fernández (2013) show that once one incorporates financial frictions in the framework, the permanent shock strongly loses importance. Likewise, a recent paper by Boz *et al.* (2011) studies a real business cycle model in which agents learn to differentiate between permanent and transitory disturbances. These authors argue that it is more severe informational frictions in EMEs that explain observed business cycle patterns even without a predominance of the non–stationary component in total factor productivity.[5]

Our work is also related to a currently active research area, which highlights the importance of fluctuations in exchange rates and asset prices for a country's

[5]Nevertheless, the notion of trend shocks as being the drivers of the business cycle can to some extent be supported by a closely related area of research in international macroeconomics. The literature on the empirics of the "intertemporal approach to the current account" highlights the importance of permanent shocks in explaining current account dynamics (see Glick and Rogoff 1995, Hoffmann 2001, Hoffmann 2003, Kano 2008, or Corsetti and Konstantinou 2012). In particular, Hoffmann and Woitek (2011) show that the world economy was predominantly characterized by permanent shocks in the period between World War I and World War II, exactly like today's emerging markets according to our findings.

external balance sheet (see Tille 2003, Gourinchas and Rey 2007a, Gourinchas and Rey 2007b, Lane and Milesi-Ferretti 2007, and Gourinchas *et al.* 2010). These changes in the net foreign asset position, which are not due to capital flows, are called *valuation effects* and drive a wedge between the change in the net foreign asset position and the current account. Accounting for the fact that EMEs are not able to borrow on international markets in their own currency, our model yields further interesting insights with respect to the role of external balance sheet effects, which, though investigated in other areas (see Céspedes *et al.* 2004, Tille 2008, or Nguyen 2011), has hitherto been unrecognized in this line of research. In particular, we find that valuation effects stabilize the change in the net foreign asset position induced by trend productivity shocks, whereas they amplify it after foreign demand shocks. In contrast, transitory technology shocks lead to valuation effects that may reinforce or mitigate the changes in the external balance sheet. Given that EMEs are characterized by a prevalence of trend shocks, we find that valuation effects act stabilizing on average.

Furthermore, the model featuring liability dollarization can account for various business cycle phenomena in EMEs. In particular, our model generates more severe macroeconomic fluctuations in EMEs than in advanced economies, and predicts a volatility of consumption that exceeds the one of output. Moreover, the model produces a countercyclical trade balance. But based on our estimation, it fails to quantitatively match the strong countercyclicality of net exports observed in the data. Finally, we show that the model succeeds in reproducing the reversal of capital flows to Mexico during the Tequila Crisis between 1994 and 1995.

The remainder of the paper is structured as follows. In the next section, we start with some descriptive business cycle statistics of selected countries and briefly discuss certain empirical features of valuation effects in EMEs. Section 2.3 outlines our benchmark model as well as the setup with liability dollarization. In Section 2.4, we describe the data and introduce our calibration and estimation technique. Estimation results are presented in Section 2.5, while Section 2.6 discusses the dynamics of our model in greater detail. Some concluding remarks appear in Section 2.7.

2.2 Descriptive Analysis

Before we introduce our theoretical framework, which we later use to investigate macroeconomic dynamics in EMEs, we take a look at some descriptive statistics first. We begin with illustrating the distinct empirical regularities about business cycles in EMEs contrary to industrialized countries. To this end, we calculate standard business cycle moments for numerous EMEs and compare them with those obtained for a group of developed small open economies. Subsequently, we document the stabilizing impact of valuation effects on the external balance sheet in EMEs.

2.2.1 Business Cycle Features

The now well–established term "Emerging Market" was originally introduced by Antoine van Agtmael in 1981, describing developing countries that experience rapid economic progress and potentially catch up with developed economies (see Van Agtmael 2007). Today, there exists a wide range of definitions of an emerging market and numerous different classifications. For that reason, we rely on three well–known classifications and focus our descriptive analysis on the so–called BRIC (Brazil, Russia, India, China) and CIVETS (Columbia, Indonesia, Vietnam, Egypt, Turkey, South Africa) countries as well as selected economies from the list of emerging markets compiled by the Dow Jones Indexes.

At this point, we use annual data from the International Financial Statistics (IFS) on output, consumption, exports, imports, and the real exchange rate.[6] For the real exchange rate we construct an index, which we normalize to 100 in the year 2005. To derive real per capita variables for output and consumption, we divide each series by population and subsequently deflate output using the GDP deflator, and consumption using the Consumer Price Index (CPI). To study business cycle fluctuations, we detrend all variables except for the net exports to output ratio. For this purpose, we apply the Hodrick and Prescott (1997) (HP)

[6]We use real exchange rates vis–à–vis the US. The choice of annual rather than higher frequency time series enables us to investigate a longer time period. Nevertheless, we did the same exercise using quarterly data and found no qualitative difference in the results.

filter on logged series with smoothing parameter 100.[7]

Descriptive sample statistics are displayed in Table 2.1. Various stylized business cycle facts are worth emphasizing.[8] First, fluctuations in macroeconomic aggregates in EMEs are generally more pronounced than in developed economies. For instance, our selected countries on the Dow Jones list exhibit average standard deviations of output, consumption and net exports that are more than twice as high as in the group of industrialized economies. This salient feature is visualized in Figure 2.1, which plots the cyclical component of GDP for each country. The graph clearly demonstrates the excess business cycle volatility in emerging markets relative to advanced economies. Second, consumption volatility exceeds output volatility in EMEs, whereas the standard deviation of consumption is on average lower than that of output in developed countries. Third, the net exports to output ratio tends to be fairly countercyclical. For instance, the mean correlation of GDP and the net exports to output ratio is as much negative as -0.45 for the CIVETS countries. By contrast, advanced economies exhibit a rather weak link between these variables. In fact, our calculations yield a correlation of merely -0.04 on average.

Somewhat surprisingly, previous studies in this line of research have not put particular focus on the business cycle features of the real exchange rate. Table 2.1 indicates that there are differences between EMEs and advanced countries along this dimension, too. The real exchange rate is more volatile in emerging markets than in developed economies. Moreover, real appreciations are associated with a fall in the trade balance to GDP ratio in EMEs. The mean correlation between these variables is -0.36 across all EMEs. On the other hand, the link between net exports and real exchange rates appears to be much weaker in the group of developed economies, for which we find basically no correlation on average.

The empirical regularities documented here are very robust. Nevertheless, we also detect some minor differences within the cohort of emerging markets. For

[7]We are aware of the shortcomings of this filtering method. Hence, we also looked at first differences of the logged series as well as cubically detrended logged series to check the robustness of our findings. Indeed, business cycle moments seem to be rather insensitive with respect to the filter choice.

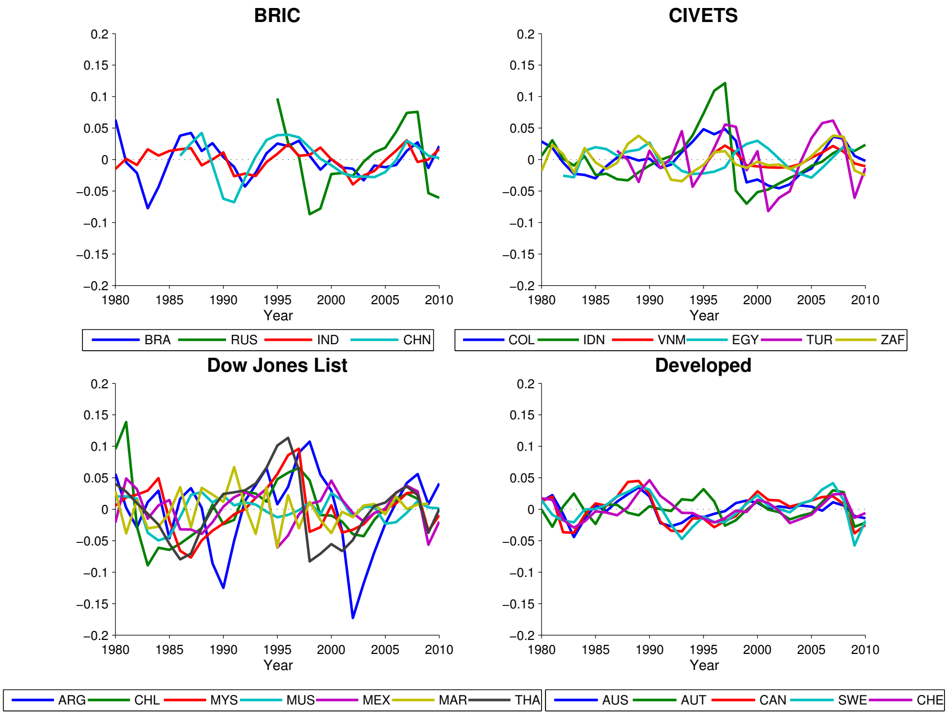
[8]We confidently call certain business cycle patterns as "stylized facts" because they have already been documented in a number of earlier studies. See, among others, Neumeyer and Perri (2005), Aguiar and Gopinath (2007), García-Cicco *et al.* (2010), and Kose and Prasad (2010).

Table 2.1: Business Cycles in EMEs and Developed Economies

	$\sigma(Y)$	$\sigma(C)$	$\sigma\left(\frac{NX}{Y}\right)$	$\sigma(e)$	$\frac{\sigma(C)}{\sigma(Y)}$	$\rho\left(\frac{NX}{Y}, Y\right)$	$\rho\left(\frac{NX}{Y}, e\right)$
BRIC							
Brazil (BRA)	2.93	12.17	2.42	21.67	4.16	−0.30	−0.37
Russia (RUS)	5.64	8.51	4.80	17.79	1.51	−0.28	−0.75
India (IND)	2.16	4.00	1.37	6.13	1.85	−0.13	−0.32
China (CHN)	3.11	3.55	2.76	7.85	1.14	0.08	0.00
Mean	3.46	7.06	2.84	13.36	2.17	−0.16	−0.36
CIVETS							
Colombia (COL)	2.65	4.70	3.44	11.50	1.78	−0.27	−0.50
Indonesia (IDN)	3.89	4.80	3.47	15.58	1.23	−0.37	−0.28
Vietnam (VNM)	1.29	2.15	4.15	6.46	1.67	−0.50	−0.54
Egypt (EGY)	1.88	2.83	4.07	22.57	1.51	−0.42	−0.54
Turkey (TUR)	4.11	6.10	2.81	9.99	1.49	−0.66	−0.68
South Africa (ZAF)	2.02	3.35	3.70	10.94	1.66	−0.47	−0.21
Mean	2.64	3.99	3.61	12.84	1.56	−0.45	−0.46
Dow Jones List							
Argentina (ARG)	5.67	10.32	3.75	30.96	1.82	−0.76	−0.29
Chile (CHL)	5.55	7.66	36.56	19.77	1.38	−0.26	0.09
Malaysia (MYS)	3.82	6.06	9.80	7.33	1.58	−0.37	−0.31
Mauritius (MUS)	4.01	7.14	5.87	7.49	1.78	−0.23	−0.40
Mexico (MEX)	3.26	5.76	3.21	11.15	1.77	−0.27	−0.65
Morocco (MAR)	3.02	3.08	4.20	9.97	1.02	−0.06	−0.03
Thailand (THA)	4.13	4.31	5.50	7.10	1.04	−0.54	−0.38
Mean	4.21	6.33	9.84	13.40	1.48	−0.36	−0.28
Mean EMEs	3.48	5.68	5.99	13.19	1.67	−0.34	−0.36
Developed							
Australia (AUS)	1.66	1.40	1.26	8.54	0.84	−0.10	0.07
Austria (AUT)	1.57	2.08	2.30	11.72	1.32	0.00	−0.13
Canada (CAN)	2.19	2.24	1.94	4.97	1.02	0.03	−0.37
Sweden (SWE)	2.12	2.21	3.12	9.80	1.04	−0.03	−0.14
Switzerland (CHE)	2.21	1.89	3.60	11.40	0.86	−0.16	0.05
Mean	1.63	1.64	2.04	7.74	0.85	−0.04	−0.09

Notes: Data are annual and taken from the IFS. All series, except for the net exports to output ratio, are real per capita variables, have been logged and filtered using the HP filter with smoothing parameter $\lambda = 100$. Standard deviations are reported in percentage points. The samples are: Brazil, 1980–2010; Russia, 1995–2010; India, 1970–2010; China, 1986–2010; Colombia, 1970–2010; Indonesia, 1970–2010; Vietnam, 1995–2010; Egypt, 1982–2009; Turkey, 1987–2010; South Africa, 1960–2010; Argentina, 1970–2010; Chile, 1970–2009; Malaysia, 1970–2010; Mauritius, 1970–2010; Mexico, 1970–2010; Morocco, 1975–2008; Thailand, 1960–2010; Australia, 1960–2010; Austria, 1978–2010; Canada, 1950–2010; Sweden, 1950–2010; and Switzerland 1970–2010.

Figure 2.1: Business Cycles in Output



Notes: Deviations of logged real GDP per capita from HP trend. Table notes of Table 2.1 on data information apply here, too.

instance, the degree of countercyclicality of the net exports to output ratio varies across EMEs. While Turkish GDP is highly negatively correlated with the net exports to output ratio, there is hardly any relation between these two variables in China. Similar discrepancies can be found regarding the excess volatility of consumption. In Mexico, the standard deviation of consumption is almost twice as high as the standard deviation of GDP. Conversely, there is virtually no excess volatility of consumption in Thailand and Morocco. Furthermore, although real depreciations are generally attended by higher net exports in EMEs, we do not observe this particular feature in Chile, China, and Morocco.

A large literature has been devoted to analyzing these business cycle phenomena in emerging markets. Yet previous studies have predominantly focused on Latin American countries. Especially, Argentina (Kydland and Zarazaga 2002, Neumeyer and Perri 2005, and García-Cicco *et al.* 2010) and Mexico (Aguiar and Gopinath 2007, Boz *et al.* 2011, and Chang and Fernández 2013) have been at the center of earlier research. Given the potential heterogeneity across EMEs, we would like to contribute to the existing literature by investigating a broader selection of countries. In the empirical part of our paper in Sections 2.5 and 2.6, we therefore parametrize our DSGE model introduced below for the emerging markets of Mexico, South Africa, and Turkey as well as the advanced economies of Canada, Sweden, and Switzerland. This allows us to get more general insights into the different business cycle patterns in these two county groups.

2.2.2 Valuation Effects

Valuation effects refer to changes in a country's net foreign asset position that do not arise from cross–border financial flows but are due to movements in asset prices or exchange rates. Accordingly, valuation effects (VAL) are the difference between the change in the net foreign asset position (ΔNFA) and the current account (CA):

$$VAL = \Delta NFA - CA.$$

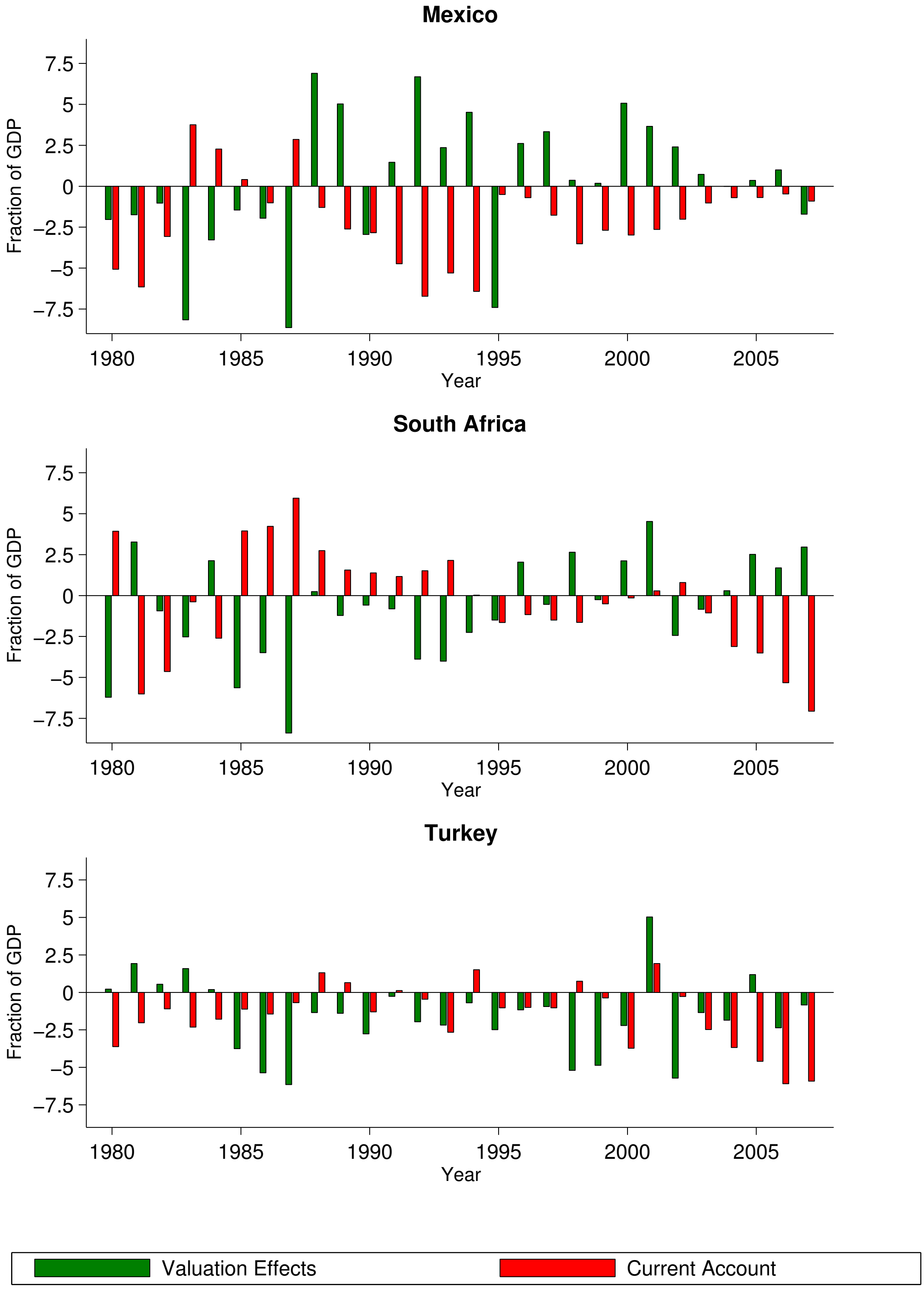
In this subsection, we investigate the relationship between valuation effects and the current account in EMEs. Our descriptive exercise relies on annual data on the stock of foreign liabilities in Mexico, South Africa, and Turkey over the time period from 1980 to 2007 provided by Lane and Milesi-Ferretti (2007). Current account data are taken from the IFS database. We use foreign debt instead of net foreign assets, because it is the empirical counterpart to the net foreign asset position in the theoretical model analyzed in this paper.[9] As a consequence, we calculate valuation effects simply by subtracting the current account from the negative change in the foreign debt position.[10]

Figure 2.2 portrays annual valuation effects as well as the current account, both as a percentage of current GDP. As is evident from the graph, there is a negative link between the current account and valuation effects. This is especially the case

[9]Note that foreign short–term debt traditionally accounts for a large part of the total external balance sheet in emerging markets (see Kose and Prasad 2010). Consequently, movements in the net foreign asset position in these countries essentially reflect changes in foreign liabilities. It is therefore not surprising that we obtained similar results when we performed this exercise based on the actual net foreign asset position.

[10]Lane and Milesi-Ferretti (2007) point out that differences between the change in the net foreign asset position and the current account may also arise from other factors than valuation effects, such as measurement errors or omissions in the data. Therefore, we have to be careful when interpreting the magnitude of valuation effects computed here.

Figure 2.2: Valuation Effects and the Current Account in Emerging Markets



Notes: Valuation effects and the current account in Mexico, South Africa and Turkey as a percentage of GDP. To compute valuation effects, we subtract the current account from the negative change in foreign liabilities. Data on foreign debt are taken from Lane and Milesi-Ferretti (2007), while current account data are retrieved from the IFS database.

for Mexico and South Africa but less obvious for Turkey. The sample correlation between the two series is -0.58, -0.75, and -0.05 for Mexico, South Africa, and Turkey, respectively. This means that a current account deficit is associated with positive valuation effects, which actually dampens the deterioration of the net foreign asset position. Hence, our descriptive analysis hints at a stabilizing nature of valuation effects.

2.3 The Model

Consider a real business cycle model of a small open economy. The domestic economy is inhabited by a unit mass of atomistic, identical, and infinitely lived households. Agents form rational expectations and seek to maximize lifetime utility by consuming two differentiated commodities: a home–produced good as well as a foreign good imported from the rest of the world. Some key ingredients of our framework are borrowed from Aguiar and Gopinath (2007). In particular, production technology features both a permanent and a transitory stochastic component. In addition, we augment our setup with financial frictions as proposed by García-Cicco *et al.* (2010). That is, agents have access to an incomplete international credit market, on which the price of debt is determined according to a debt–elastic interest rate rule.

In what follows, we choose the domestically produced good as numéraire and normalize its price in the home country to one, i.e. $p_{H,t} = 1$. Thus, all variables are expressed in units of the home good. Section 2.3.1 presents our *benchmark model*. In Section 2.3.2, we introduce a further financial distortion in our framework by assuming that domestic agents can only borrow in foreign currency on international capital markets. We call this modified setup the *liability dollarization model*. Section 2.3.3 provides a summary of both models and shows how we solve them. A detailed description of the liability dollarization model including the derivation of optimality and steady state conditions is presented in Appendix A.1.

2.3.1 Benchmark Model

Producing Economy

The home economy produces a differentiated domestic final good in a perfectly competitive environment. Technology is described by a neoclassical production function of the form

$$Y_t = z_t K_t^{\alpha} (\Gamma_t l_t)^{1-\alpha}, \tag{2.1}$$

with Y_t, l_t, K_t, and α denoting aggregate output of the home good, labor input, aggregate capital, and the economy's capital share, respectively. Moreover, z_t and Γ_t describe two different exogenous technology processes. On the one hand, the economy is exposed to transitory fluctuations in total factor productivity captured by z_t, which follows a stationary first–order autoregressive (AR) process in logs:

$$z_t = z_{t-1}^{\rho_z} \exp(\epsilon_t^z), \quad \text{with} \quad \epsilon_t^z \sim \mathcal{N}(0, \sigma_z^2). \tag{2.2}$$

On the other hand, we build on Aguiar and Gopinath (2007) and assume that the producing economy is not only hit by transitory shocks but also by trend shocks. For this reason, production technology features a non–stationary labor augmenting productivity component represented by Γ_t, which equals the cumulative product of growth shocks:

$$\Gamma_t = g_t \Gamma_{t-1} = \prod_{s=0}^{t} g_s, \quad \text{where} \quad g_t = \mu_g^{1-\rho_g} g_{t-1}^{\rho_g} \exp(\epsilon_t^g), \quad \text{with} \quad \epsilon_t^g \sim \mathcal{N}(0, \sigma_g^2). \tag{2.3}$$

The underlying structure of the non–stationary technology process implies that a realization of g_s will never die out and therefore has a permanent impact on Γ_t, for all $t \geq s$. Parameters $|\rho_z| < 1$ and $|\rho_g| < 1$ determine the persistence of the two exogenous processes. ϵ_t^z and ϵ_t^g represent shocks to the transitory and permanent technology process, respectively, with σ_z^2 and σ_g^2 being the corresponding variances. Finally, μ_g refers to the long–term or steady state gross growth rate of the economy.

Let I_t denote investment in the capital stock at date t. The evolution of the capital stock is described by the following law of motion:

$$K_{t+1} = (1-\delta)K_t + I_t - \frac{\phi}{2}\left(\frac{K_{t+1}}{K_t} - \mu_g\right)^2 K_t. \tag{2.4}$$

The last term in equation (2.4) introduces quadratic capital adjustment costs. Parameter ϕ determines the weight of adjustment costs and δ is the depreciation rate.

Representative Household

The representative household's objective is to maximize expected lifetime utility

$$\mathrm{E}_t \sum_{\tau=t}^{\infty} \beta^{\tau-t} u(C_\tau, 1-l_\tau), \tag{2.5}$$

where $\beta \in (0,1)$ is the subjective discount factor, $u(.)$ is period utility, which is assumed to be increasing and strictly concave in both arguments, and $(1-l_t)$ denotes time spent on leisure activities in period t. C_t is a composite consumption index characterized by a standard Dixit and Stiglitz (1977) Constant Elasticity of Substitution (CES) aggregate:

$$C_t = \left[\theta^{\frac{1}{\eta}} C_{H,t}^{\frac{\eta-1}{\eta}} + (1-\theta)^{\frac{1}{\eta}} C_{F,t}^{\frac{\eta-1}{\eta}}\right]^{\frac{\eta}{\eta-1}},$$

where $\theta \in (0,1)$ is the share of home goods in consumption, and $\eta \in (0,\infty)$ is the elasticity of intratemporal substitution between differentiated home and foreign goods. Consequently, $C_{H,t}$ and $C_{F,t}$ correspond to consumption of the home and foreign good, respectively.

We follow Aguiar and Gopinath (2007) and assume that preferences are described by a canonical Cobb–Douglas Constant Relative Risk Aversion (CRRA) utility function:[11]

$$u(C_t, 1 - l_t) = \frac{\left[C_t^{\gamma}(1 - l_t)^{1-\gamma}\right]^{1-\sigma}}{1 - \sigma},$$

where σ co–determines the degree of relative risk aversion, and $\gamma \in (0, 1)$ describes the consumption weight in utility.[12]

Our theoretical economy features only one non–contingent financial asset. At each time t, the representative agent can issue D_{t+1} one–period bonds on international capital markets at a predetermined risk–free rate r_t. Accordingly, the household faces the following period resource constraint:

$$Y_t + D_{t+1} \geq p_t C_t + I_t + D_t(1 + r_{t-1}), \tag{2.6}$$

where p_t denotes the price of composite consumption. Equation (2.6) embeds the standard interpretation. It simply requires that total expenditures at date t in form of consumption, investment and debt repayments (RHS) are financed by income plus new loans (LHS).

Since variables Y_t, C_t, $C_{H,t}$, $C_{F,t}$, I_t, K_t, and D_t exhibit a stochastic trend, they need to be detrended in order to ensure stationarity of the system. Let lower case letters x_t indicate the stationary counterpart of X_t. We can then detrend our relevant variables in a straightforward manner:

$$x_t \equiv \frac{X_t}{\Gamma_{t-1}}.$$

We can now return to the optimization rationale of the representative agent stated in (2.5). We can split the problem into two stages: *intratemporal* and *intertemporal* optimization. First, *intratemporal* household optimization yields the

[11]This instantaneous utility function is non–separable in consumption and leisure and thereby leads to income effects on labor supply. A number of studies in this strand of the literature (Mendoza 1991, Neumeyer and Perri 2005, García-Cicco *et al.* 2010, Boz *et al.* 2011, and Chang and Fernández 2013) use a quasi–linear period utility function pioneered by Greenwood *et al.* (1988), so–called GHH preferences, and generalized by Jaimovich and Rebelo (2009). A key characteristic of this preference specification is that it rules out any income effects on labor supply.

[12]Note that this functional form of utility implies that the Arrow–Pratt measure of relative risk aversion corresponds to $1 - \gamma(1 - \sigma)$ rather than σ. Accordingly, the elasticity of intertemporal substitution is given by $\frac{1}{1-\gamma(1-\sigma)}$.

following demand functions for the home and foreign consumption good:

$$c_{H,t} = \theta p_t^{\eta} c_t, \tag{2.7}$$

and

$$c_{F,t} = (1-\theta)\left(\frac{p_t}{p_{F,t}}\right)^{\eta} c_t. \tag{2.8}$$

In addition, the price index of composite consumption is determined by

$$p_t = \left[\theta + (1-\theta) p_{F,t}^{1-\eta}\right]^{\frac{1}{1-\eta}}, \tag{2.9}$$

where $p_{F,t}$ denotes the price of the foreign good expressed in units of the home–produced good.

Next, we consider the *intertemporal* optimization problem. Final good producing firms are owned by the representative household, who hires labor and rents capital for which it pays competitive prices. Thus, we can combine the detrended versions of the production function (2.1), the law of motion of capital (2.4), and the aggregate resource constraint (2.6) to state the stationary maximization problem at time t as

$$\max_{\{c_\tau, l_\tau, k_{\tau+1}, d_{\tau+1}\}} \mathrm{E}_t \sum_{\tau=t}^{\infty} \beta^{\tau-t} (\Gamma_{\tau-1}^{\gamma(1-\sigma)} u(c_\tau, 1-l_\tau))$$

s.t.

$$y_\tau + (1-\delta)k_\tau + g_\tau d_{\tau+1} \geq p_\tau c_\tau + g_\tau k_{\tau+1} + \frac{\phi}{2}\left(g_\tau \frac{k_{\tau+1}}{k_\tau} - \mu_g\right)^2 k_\tau + d_\tau(1+r_{\tau-1}),$$

taking as given k_t, d_t, as well as the transversality condition $\lim_{j\to\infty} \mathrm{E}_t\left[\prod_{s=0}^{j-2} \frac{d_{t+j}}{1+r_{t+s}}\right] = 0$. The solution to this maximization problem renders the following optimality conditions:

$$\frac{1}{c_t}\left(c_t^{\gamma}(1-l_t)^{1-\gamma}\right)^{1-\sigma} = g_t^{\gamma(1-\sigma)-1} \beta \mathrm{E}_t\Bigg[\frac{1}{c_{t+1}}\left(c_{t+1}^{\gamma}(1-l_{t+1})^{1-\gamma}\right)^{1-\sigma} \cdot \frac{p_t\left(\alpha\frac{y_{t+1}}{k_{t+1}} + (1-\delta) + \phi\left(g_{t+1}\frac{k_{t+2}}{k_{t+1}} - \mu_g\right)g_{t+1}\frac{k_{t+2}}{k_{t+1}} - \frac{\phi}{2}\left(g_{t+1}\frac{k_{t+2}}{k_{t+1}} - \mu_g\right)^2\right)}{p_{t+1}\left(1 + \phi\left(g_t\frac{k_{t+1}}{k_t} - \mu_g\right)\right)}\Bigg], \tag{2.10}$$

$$\frac{1}{c_t}\left(c_t^{\gamma}(1-l_t)^{1-\gamma}\right)^{1-\sigma} = \beta g_t^{\gamma(1-\sigma)-1}\mathrm{E}_t\left[\frac{1}{c_{t+1}}\left(c_{t+1}^{\gamma}(1-l_{t+1})^{1-\gamma}\right)^{1-\sigma}\frac{p_t}{p_{t+1}}\right](1+r_t), \qquad (2.11)$$

and

$$p_t\frac{1-\gamma}{\gamma}\frac{c_t}{1-l_t} = (1-\alpha)\frac{y_t}{l_t}. \qquad (2.12)$$

Equations (2.10) and (2.11) represent the intertemporal Euler Equations with respect to capital and bond holdings, respectively. Condition (2.12) specifies the standard labor–leisure trade–off.

International Prices and Trade

Interest Rates

We assume that the interest rate r_t on international debt borrowed at date t and due in period $t+1$ is increasing in expected future external debt relative to income:

$$r_t = r + \psi\Bigg(\exp\left(\mathrm{E}_t\left[\frac{D_{t+1}}{Y_{t+1}}\right] - \frac{D}{Y}\right) - 1\Bigg). \qquad (2.13)$$

The reason why we introduce this interest rate rule in our setup is twofold. First, as Schmitt-Grohé and Uribe (2003) point out, it is a convenient way to make the deterministic equilibrium independent of initial conditions and thus to close the model. Second, it allows us to feature financial frictions in our theoretical economy in a reduced form.

According to equation (2.13), the cost of debt depends on the steady state interest rate r, the economy's steady state debt to GDP ratio $\frac{D}{Y}$, and the expected level of debt over GDP in the next period $\mathrm{E}_t\left[\frac{D_{t+1}}{Y_{t+1}}\right]$. Note that for ease of interpretation we use the debt to GDP ratio to determine the interest rate rather than the level of total debt. Intuitively, a country finds it hard to borrow on soft terms and is charged a premium over the equilibrium interest rate if it is expected to face high debt relative to the size of its economy in the future.[13]

[13] Admittedly, there is no micro foundation upon which we build our interest rate rule. Nevertheless, the imposed positive relationship between debt over GDP and borrowing costs in our framework is consistent with findings in the sovereign debt literature. For instance, Arellano (2008) develops a model, which shows how higher indebtedness increases the probability of default and thus raises the interest rate. Likewise, a large body of empirical research has emphasized the importance of a country's external debt in explaining interest rate spreads (see Uribe and Yue 2006). Furthermore, as Uribe (2006) demonstrates, we could also introduce a borrowing con-

In our benchmark setup, we follow García-Cicco *et al.* (2010) and interpret ψ as a catchall parameter for financial frictions and financial development. A high value of ψ implies that the interest rate reacts more sensitively to changes in the expected future debt to GDP ratio, which reflects severe capital market distortions in the economy.[14] García-Cicco *et al.* (2010) highlight the importance of the size of ψ for the analysis of business cycles in both developed economies and EMEs. In light of this, our empirical analysis below permits ψ to take on values that are substantially greater than zero. Therefore, we allow for variation in the interest rate, which entails important implications for the dynamics in our model.[15]

Exchange Rate

The household's optimization problem abroad is analogous to the home country. Since we consider an SOE framework, the home economy is infinitesimally small relative to the rest of the world. That is, the foreign country is approximately closed and only consumes goods produced abroad. As a result, the foreign price index of the foreign consumption composite $p_t^\star$ boils down to the foreign price of goods produced in the rest of the world $p_{F,t}^\star$, i.e. $p_t^\star = p_{F,t}^\star$. We assume that the law of one price holds such that

$$p_{F,t} = \frac{p_{F,t}^\star}{s_t} = \frac{p_t^\star}{s_t},$$

straint in our small open economy framework to generate an endogenous country spread. In such a model, a premium over the equilibrium interest rate emerges if the debt ceiling is binding. In light of this, we believe that our interest rate rule provides a convenient way to capture credit market imperfections even though it leaves out an endogenous explanation within the model.

[14] At this point it is intuitive to look at the log–linearized version of the interest rate rule given by

$$\widehat{r_t}\, r = \frac{d}{y}\psi \mathrm{E}_t\left[\widehat{d_{t+1}} - \widehat{y_{t+1}}\right] \qquad \Leftrightarrow \qquad \frac{\Delta r_t}{\Delta \mathrm{E}_t\left[\left(\frac{d}{y}\right)_{t+1}\right]} \approx \psi,$$

where hatted variables denote log–deviations from steady state and Δ indicates absolute changes. Accordingly, $\widehat{r_t} \cdot r$ approximately corresponds to the absolute deviation of the interest rate from its steady state value r. Hence, we can identify the effective debt–elasticity of the interest rate as $\frac{\psi}{r} \cdot \frac{d}{y}$. More specifically, parameter ψ determines by how many percentage points the interest rate at date t increases if, *ceteris paribus*, we expect the debt to income ratio to rise by one percentage point in period $t + 1$.

[15] ψ needs to be positive in order to induce stationarity. However, Aguiar and Gopinath (2007) and other related studies set ψ equal to 0.001, i.e. virtually equal to zero. In doing so, these authors basically shut down interest rate changes and thereby eliminate any feedback effects from the interest rate on other macroeconomic variables (see García-Cicco *et al.* 2010).

where $s_t = p^{\star}_{H,t}$ defines the price of the home good in the foreign country. In fact, s_t can be interpreted as the "nominal exchange rate" determining the price of the domestic currency in terms of the foreign currency, since we have normalized the domestic price of the home good to one ($p_{H,t} = 1$). As a result, we can define the real exchange rate as the price of the domestic composite consumption good in units of the foreign composite consumption good:

$$e_t = \frac{p_t s_t}{p^{\star}_t} = \frac{p_t s_t}{p^{\star}_{F,t}} = \frac{p_t s_t}{p_{F,t} s_t} = \frac{p_t}{p_{F,t}}. \tag{2.14}$$

Net Exports and Current Account

We assume that the consumption index of agents abroad is also characterized by a CES aggregate. For simplicity, we also assume that variables in the domestic economy and the rest of the world exhibit the same stochastic trend component, i.e. $\Gamma_{t-1} = \Gamma^{\star}_{t-1}$. Let $c^{\star}_t$ denote detrended foreign consumption such that we can derive foreign demand for the home good, from the perspective of the home country, as

$$c^{\star}_{H,t} = \theta^{\star} p^{\eta^{\star}}_{F,t} c^{\star}_t, \tag{2.15}$$

where $\theta^{\star} \in (0, 1)$ denotes the share of home goods in foreign consumption, and $\eta^{\star} \in (0, \infty)$ is the elasticity of intratemporal substitution abroad.

Consequently, net exports in the home economy can be easily calculated as the difference between exports and imports:

$$nx_t = c^{\star}_{H,t} - p_{F,t} c_{F,t}. \tag{2.16}$$

Furthermore, the current account is given by the trade balance minus interest payments on external debt:

$$ca_t = -r_{t-1} d_t + nx_t. \tag{2.17}$$

As in any standard intertemporal model of the current account (see Obstfeld and Rogoff 1996), the current account in our benchmark economy simply equals the change in the country's net foreign asset position:

$$\Delta nfa_{t+1} = -g_t d_{t+1} + d_t = ca_t. \tag{2.18}$$

General Equilibrium

In a general equilibrium, all markets have to clear. Equilibrium in the market for the home–produced good requires that output equals domestic absorption plus foreign demand:

$$y_t = c_{H,t} + i_t + c^{\star}_{H,t}. \tag{2.19}$$

Finally, foreign consumption is assumed to follow an exogenous first–order AR process in logs:

$$c^{\star}_{t+1} = (c^{\star}_t)^{\rho_c} \exp(\epsilon^c_{t+1}), \quad \text{with} \quad \epsilon^c_t \sim \mathcal{N}(0, \sigma^2_c). \tag{2.20}$$

This specification introduces external disturbances in our setup, which potentially allows foreign demand shocks, along with permanent and transitory productivity shocks, to drive the dynamics in the model.

2.3.2 Liability Dollarization

A well–known characteristic of EMEs is that they have had difficulties in borrowing in their own currencies on international capital markets.[16] In fact, the bulk of external debt in these countries has traditionally been issued in major currencies like US dollar, euro, sterling, or Swiss francs (see Eichengreen *et al.* 2005). Being denominated in foreign currency, the amount of outstanding loans is subject to substantial exchange rate fluctuations which may induce non–negligible external balance sheet effects. In order to account for this phenomenon, which is often referred to as *liability dollarization*, we now extend our benchmark framework from the previous subsection along this dimension.

The basic structure of the model coincides with our benchmark model. Thus, most of equations and optimality conditions from Section 2.3.1 simply carry over.

[16] This phenomena has been documented by an extensive literature. See, for instance, Reinhart *et al.* (2003), Lane and Shambaugh (2010) and contributions in Eichengreen and Hausmann (2005).

As we have set up our model in real terms, liability dollarization means that the home country can only borrow in units of foreign consumption. Accordingly, the resource constraint of the economy adjusts to[17]

$$Y_t + p_t \frac{D_{t+1}}{e_t} \geq p_t C_t + I_t + p_t \frac{D_t}{e_t}(1 + r_{t-1}). \tag{2.21}$$

This has an immediate impact on household optimization such that we obtain an intertemporal Euler Equation with respect to foreign debt of

$$\frac{1}{c_t}\left(c_t^{\gamma}(1-l_t)^{1-\gamma}\right)^{1-\sigma} = \beta g_t^{\gamma(1-\sigma)-1} \mathrm{E}_t \left[\frac{1}{c_{t+1}}\left(c_{t+1}^{\gamma}(1-l_{t+1})^{1-\gamma}\right)^{1-\sigma} \frac{e_t}{e_{t+1}}\right](1+r_t). \tag{2.22}$$

Note that liability dollarization changes the price of consumption at date t expressed in units of date $t+1$ relative to the benchmark case in equation (2.11). In particular, it alters the impact of the exchange rate fluctuations on the optimal intertemporal consumption allocation of the representative household.

In addition, our interest rate rule modifies to

$$r_t = r + \psi\left(\exp\left(\mathrm{E}_t\left[\frac{p_{t+1}D_{t+1}}{e_{t+1}Y_{t+1}}\right] - \frac{pD}{eY}\right) - 1\right). \tag{2.23}$$

It is worth emphasizing that with interest rates determined by equation (2.23), parameter ψ can no longer be interpreted as a catchall variable for financial frictions as we do in the benchmark economy (see equation (2.13)). When households issue new debt, they do not know how much they have to repay in the future because exchange rate variations change the value of outstanding debt. Hence, the fact that countries are forced to borrow in foreign currency itself represents a special form of capital market distortions. In the model at hand we can therefore encompass the extent of financial frictions by the interplay of liability dollarization and debt–elastic interest rates.[18]

[17]Note that international debt D is expressed in units of the foreign composite consumption good such that $\frac{D}{e}$ is denoted in units of the domestic consumption good. Hence, we have to multiply $\frac{D}{e}$ by the price of domestic consumption p in order to obtain foreign debt expressed in units of the home–produced good.

[18]Note that the log–linearized version of the interest rate rule is given by

$$\widehat{r_t}\, r = \frac{pd}{ey}\psi \mathrm{E}_t\left[\widehat{p_{t+1}} + \widehat{d_{t+1}} - \widehat{y_{t+1}} - \widehat{e_{t+1}}\right] \qquad \Leftrightarrow \qquad \frac{\Delta r_t}{\Delta \mathrm{E}_t\left[\left(\frac{pd}{ey}\right)_{t+1}\right]} \approx \psi.$$

Importantly, the value of outstanding international debt depends on the evolution of the real exchange rate. As a result, the change in the country's net foreign asset position no longer equals the current account but is now adjusted for valuation effects stemming from exchange rate changes. We can write the detrended current account as

$$ca_t = nx_t - r_{t-1} p_t \frac{d_t}{e_t}. \tag{2.24}$$

Moreover, we derive the change in detrended net foreign assets as the sum of the current account and valuation effects:

$$\begin{aligned}
& & \Delta nfa_t &= -g_t p_t \frac{d_{t+1}}{e_t} + p_{t-1} \frac{d_t}{e_{t-1}} && (2.25)\\
&\overset{(2.21)}{\iff} & \Delta nfa_t &= y_t - p_t c_t - i_t - r_{t-1} p_t \frac{d_t}{e_t} + p_{t-1} \frac{d_t}{e_{t-1}} - p_t \frac{d_t}{e_t} \\
&\overset{(2.19)}{\iff} & \Delta nfa_t &= c^{\star}_{H,t} - p_{F,t} c_{F,t} - r_{t-1} p_t \frac{d_t}{e_t} + d_t \left(\frac{p_{t-1}}{e_{t-1}} - \frac{p_t}{e_t} \right) \\
&\overset{(2.16)}{\iff} & \Delta nfa_t &= nx_t - r_{t-1} p_t \frac{d_t}{e_t} + d_t \left(\frac{p_{t-1}}{e_{t-1}} - \frac{p_t}{e_t} \right) \\
&\overset{(2.24)}{\iff} & \Delta nfa_t &= ca_t + val_t.
\end{aligned}$$

Hence, the stationary version of valuation effects at date t is given by

$$val_t = d_t \left(\frac{p_{t-1}}{e_{t-1}} - \frac{p_t}{e_t} \right). \tag{2.26}$$

2.3.3 Model Solution

Once the variables incorporating the stochastic permanent component have been detrended, the models introduced above constitute stationary systems of non–linear expectational difference equations. In the benchmark model the system is featured by 18 variables (y_t, c_t, r_t, e_t, i_t, l_t, $c_{H,t}$, $c_{F,t}$, $c^{\star}_{H,t}$, p_t, $p_{F,t}$, nx_t, ca_t, k_t, d_t, z_t, g_t, $c^{\star}_t$) in the stationary versions of equations (2.1), (2.2), (2.3), (2.4), (2.6), (2.7), (2.8), (2.9), (2.10), (2.11), (2.12), (2.13), (2.14), (2.15), (2.16), (2.17), (2.19), and (2.20). The model with liability dollarization forms a system of 20 variables (y_t, c_t, r_t, e_t, i_t, l_t, $c_{H,t}$, $c_{F,t}$, $c^{\star}_{H,t}$, p_t, $p_{F,t}$, nx_t, ca_t, Δnfa_t, val_t, k_t, d_t, z_t, g_t, $c^{\star}_t$) in the detrended versions of equations (2.1), (2.2), (2.3), (2.4), (2.7), (2.8), (2.9), (2.10), (2.12), (2.14), (2.15), (2.16),

The interpretation of the size of parameter ψ is the same as in the benchmark case.

(2.19), (2.20), (2.21), (2.22), (2.23), (2.24), (2.25), and (2.26).

For each setup, we use a first–order approximation of the respective model solution and log–linearize the system around its deterministic steady state (See Appendix A.2). All equations being log–linearized, we end up with a linear system of first–order expectational difference equations, which we solve using the method proposed by Klein (2000). The solution yields a state space representation

$$\begin{aligned} \mathbf{y}_t &= \mathbf{Z}\boldsymbol{\alpha}_t \\ \boldsymbol{\alpha}_t &= \mathbf{T}\boldsymbol{\alpha}_{t-1} + \mathbf{R}\boldsymbol{\eta}_t, \end{aligned} \tag{2.27}$$

where $\mathbf{y}_t$ is an $(n \times 1)$ vector of control variables and $\boldsymbol{\alpha}_t$ is the $(m \times 1)$ unobservable state vector, which is driven by the exogenous processes $\boldsymbol{\eta}_t$ of dimension $(x \times 1)$. Therefore, the matrix $\mathbf{R}$, which links the state variables to the exogenous processes, has dimension $(m \times x)$.[19] This representation enables us to estimate certain structural parameters of our models using country–specific data, which will be described in detail in the next section.

2.4 Estimation and Calibration

To gauge the models' ability to explain macroeconomic dynamics in EMEs, we quantify our theoretical economy for three EMEs: Mexico, South Africa, and Turkey. Furthermore, to assess the peculiarity of business cycles in emerging markets, we also parametrize the benchmark model for a group of developed small open economies, represented by Canada, Sweden, and Switzerland.

We choose a mixture of country–specific calibration and Bayesian estimation. In particular, we estimate the parameters determining the exogenous processes in the model as well as the debt–elasticity of the interest rate ψ. All other parameters are calibrated. Given our focus on the role of liability dollarization as a form of financial frictions in EMEs, we estimate both models for Mexico, South Africa, and Turkey, whereas for our developed economies, we only analyze the benchmark framework.

[19] Accordingly, in the benchmark model, we have $x = 3$, $m = 5$, and $n = 13$. In the liability dollarization model, we have $x = 3$, $m = 5$, and $n = 15$.

2.4.1 Data

The time unit t in our theoretical economy is counted as quarters. To estimate our linearized models, we use quarterly time series on real per capita GDP and consumption, real interest rates and real exchange rates. All data are taken from the IFS database. The time series of real per capita output and consumption are seasonally adjusted using the Census Bureau's X–12 ARIMA procedure. Our selection of countries and sample period is motivated by data availability and comparability with existing literature. Table 2.2 summarizes the sample period used for estimation for each country.

Table 2.2: Data for Estimation

Emerging Markets		Developed Economies	
Mexico (MEX)	1981Q1–2011Q4	Canada (CAN)	1960Q1–2011Q4
South Africa (ZAF)	1960Q1–2011Q4	Sweden (SWE)	1981Q1–2011Q4
Turkey (TUR)	1987Q1–2011Q4	Switzerland (CHE)	1970Q1–2011Q3

Notes: All data are taken from the IFS database. Variables used for estimation are real GDP per capita, real consumption per capita, the real interest rate, and the real exchange rates.

To calculate real per capita variables, we divide the respective nominal series by population and subsequently deflate output using the GDP deflator and consumption using the CPI. Population data are only available on an annual frequency. Hence, we pin down population in the respective second quarter at the reported annual figure and interpolate missing data points using annual growth rates. Our construction of real interest rates is similar to the approach chosen by Neumeyer and Perri (2005). That is, we subtract domestic expected inflation based on the GDP deflator from the annual nominal interest rate, which is then transformed into a 3–month rate.[20] Expected inflation is calculated as the average of actual inflation in the current period and the three previous quarters. Finally, for each country we construct a real exchange rate index, which is normalized to 100 in 2005Q2 by multiplying the respective nominal US dollar exchange rate (US dollar per national currency) by the domestic CPI and dividing by the US

[20]For Canada, Mexico, South Africa, Sweden, and Switzerland we use T–bill rates, whereas for Turkey we take the deposit rate. Note that Neumeyer and Perri (2005) subtract expected US inflation from the dollar interest rate based on the J.P. Morgan Emerging Market Bond Index (EMBI) spread. We use domestic expected inflation instead because our model describes the behavior of a domestic representative agent as opposed to an international investor.

CPI. Moreover, we follow García-Cicco *et al.* (2010) and filter our data prior to estimation by removing the cubic trend from the real series in logs.

2.4.2 Calibration

Table 2.3 reports the calibration of our parameters. We keep the majority of structural parameters constant across both models and countries, and assign conventional values suggested by previous literature. In doing so, we try to retain a high degree of comparability with earlier contributions. In particular, we follow Aguiar and Gopinath (2007) and set the subjective discount factor β equal to 0.98, the weight of consumption in the utility function γ equal to 0.36, the parameter governing the curvature of the utility function σ equal to 2, the weight of the adjustment costs ϕ equal to 4, the capital share in the production function equal to 0.32, and the rate of depreciation δ equal to 0.05. Without loss of generality, we normalize the mean value of both the transitory productivity process z and the foreign consumption process $c^\star$ to 1. There is no consensus in the literature concerning which value to choose for the elasticity of intratemporal substitution between home and foreign goods (see Obstfeld and Rogoff 2000). We assume that the price elasticity of goods is the same throughout the world and follow Corsetti and Pesenti (2001) by setting its value equal to unity, i.e. $\eta = \eta^\star = 1$. Moreover, we pin down $\theta = 0.8$ and $\theta^\star = 0.2$ to match a consumption import share both at home and abroad of 20 percent. This choice is motivated by empirical figures reported in Burstein *et al.* (2005).

Two parameters are fixed country–specifically. We calibrate the mean of the non–stationary productivity process μ_g at the average quarterly gross growth rate of real per capita GDP. We pin down the steady state external debt to GDP ratio at the average annual net foreign asset position.[21] That is, we set $\frac{D}{Y}$ in the benchmark model and $\frac{pD}{eY}$ in the model with liability dollarization equal to 35.63 percent, 24.36 percent, 23.20 percent, 31.08 percent, and 18.63 percent for Mexico, South Africa, Turkey, Canada, and Sweden, respectively. Switzerland is a net creditor to the rest of the world and thus exhibits a positive average net foreign asset position

[21] Average net foreign asset positions are calculated based on annual data between 1970 and 2007 collected by Lane and Milesi-Ferretti (2007).

relative to GDP of 90 percent.

Table 2.3: Calibrated Values

		General Parameters			
β	discount factor	0.98	$\theta^\star$	foreign share of home goods	0.20
γ	consumption weight in utility	0.36	η	domestic elasticity of intratemporal substitution	1.00
σ	curvature of utility	2.00			
ϕ	weight of adjustment costs	4.00	$\eta^\star$	foreign elasticity of intratemporal substitution	1.00
α	capital share	0.32			
δ	depreciation rate	0.05	z	mean of z process	1.00
θ	domestic share of home goods	0.80	$c^\star$	mean of $c^\star$ process	1.00
		Country–specific Parameters			
$\left(\frac{p}{e}\cdot\right)\frac{D}{Y}$	external debt ratio		μ_g	mean gross growth rate	
	MEX	0.36		MEX	1.0018
	ZAF	0.24		ZAF	1.0026
	TUR	0.23		TUR	1.0063
	CAN	0.31		CAN	1.0049
	SWE	0.19		SWE	1.0046
	CHE	−0.90		CHE	1.0029

Notes: In the benchmark model, we pin down $\frac{D}{Y}$. In the model with liability dollarization, we calibrate $\frac{pD}{eY}$ at the reported value of the external debt to income ratio.

2.4.3 Estimation

Similar to recent studies in this field of research (e.g. García-Cicco *et al.* 2010 or Chang and Fernández 2013), we adopt a Bayesian viewpoint. Besides computational advantages, this allows us to incorporate prior beliefs about the structural parameters in a straightforward manner. As pointed out above, the size of parameter ψ, which determines the debt–elasticity of interest rates, may have important implications for the dynamics in the model. However, ex–ante we do not have strong beliefs about the size of the debt–elasticity of interest rates. To this end, we estimate parameter ψ as well as the parameters governing the exogenous structural shocks in the model.

A major contribution of this work is that our estimation procedure allows for a dynamic structure in the "measurement error", which captures the off–model dynamics in the data. To our knowledge, this represents a novel approach in this strand of the literature. Related previous studies deal differently with the crucial issue on how to address these residual dynamics of our observable variables in the estimation.[22] Naturally, our SOE setup is too stylized to account for all the dynamics in real macroeconomic time series. Hence, we build on Sargent (1989) and Ireland (2004) and include a (vector–)autoregressive "measurement error" component to capture the dynamics in the data that cannot be replicated by the structural model itself. Accordingly, our state space representation in equation (2.27) modifies to

$$\begin{aligned}
\mathbf{y}_t &= \mathbf{Z}\boldsymbol{\alpha}_t + \boldsymbol{\epsilon}_t \\
\boldsymbol{\alpha}_t &= \mathbf{T}\boldsymbol{\alpha}_{t-1} + \mathbf{R}\boldsymbol{\eta}_t, \qquad \boldsymbol{\eta}_t \sim \mathcal{N}(\mathbf{0}, \boldsymbol{\Sigma}) \\
\boldsymbol{\epsilon}_t &= \mathbf{A}\boldsymbol{\epsilon}_{t-1} + \boldsymbol{\xi}_t, \qquad \boldsymbol{\xi}_t \sim \mathcal{N}(\mathbf{0}, \boldsymbol{\Omega})
\end{aligned} \tag{2.28}$$

where $\boldsymbol{\epsilon_t}$ is an $(n_{estimation} \times 1)$ vector of measurement errors and $n_{estimation}$ denotes the number of observables we use for estimation, which is four in our case. We assume that the off–model dynamics inherent in each variable follow an autoregressive process such that all off–diagonal entries of the $(n_{estimation} \times n_{estimation})$ coefficient matrix $\mathbf{A}$ are restricted to zero.

We apply a Markov Chain Monte Carlo (MCMC) simulation using the Metropolis–Hastings algorithm within the Gibbs sampler[23] to derive the posterior distributions of the parameters. First, we implement Gibbs sampling to simulate the posteriors of the parameters defining our exogenous processes $\rho_z, \sigma_z^2, \rho_g, \sigma_g^2, \rho_c$ and σ_c^2, $\mathbf{A}$, and $\boldsymbol{\Omega}$. Then, at each simulation iteration, conditional on the current Gibbs draw, we add a Metropolis–Hastings step in order to approximate the posterior distribution of ψ. We therefore apply a random walk Metropolis Hastings algorithm, in which we choose the variance of the proposal density such that we get an acceptance ratio of about 20 to 40 percent. We estimate the whole model with different starting values in order to control for the possibility of multiple modes in the posterior distribution.

Apart from the volatility in the off–model dynamics, our prior beliefs are constant across all models and countries. They are summarized in Table 2.4. We

[22] For instance, García-Cicco *et al.* (2010) and Chang and Fernández (2013) impose a simple White Noise process on the measurement error. In addition, García-Cicco *et al.* (2010) tightly restrict the variance of the measurement error, so that it cannot explain more than 6 percent of the variation in the respective observable variable.

[23] See Appendix C.4 for further detail regarding the estimation algorithm.

impose a normal distribution with mean 0.5 and variance 0.02 on the autoregressive coefficients of structural shocks. Regarding the persistence parameters of measurement errors, it is more difficult to come up with informative priors. Therefore, we implement rather diffuse priors and assume they follow a normal distribution with zero mean and variance 0.05. Since the normal distribution has infinite support, we enforce stationarity by restricting the AR coefficients to lie within the unit circle. Priors on the volatility of the structural exogenous processes are harmonized and are described by an inverse Gamma distribution with shape parameter 2.05 and scale factor 0.0105.[24] Furthermore, we fix the prior distribution of the measurement error variance country–specifically such that its mean matches the variance of the respective observable time series used for estimation. Finally, we impose a fairly flat uniform distribution with support $[0.001, 5]$ on our financial frictions parameter ψ.

Table 2.4: Prior Distributions

	Prior Dist.	Prior 90% Bands	Prior Dist.	Prior 90% Bands	Prior Dist.	Prior 90% Bands
			HARMONIZED PRIORS			
ψ			$\mathcal{U}(0.001, 5)$	–		
ρ_z			$\mathcal{N}(0.5, 0.02)$	[0.269,0.733]		
ρ_g			$\mathcal{N}(0.5, 0.02)$	[0.269,0.733]		
ρ_c			$\mathcal{N}(0.5, 0.02)$	[0.269,0.733]		
ρ_{ϵ_y}			$\mathcal{N}(0, 0.05)$	[−0.367,0.367]		
ρ_{ϵ_c}			$\mathcal{N}(0, 0.05)$	[−0.367,0.367]		
ρ_{ϵ_r}			$\mathcal{N}(0, 0.05)$	[−0.367,0.367]		
ρ_{ϵ_e}			$\mathcal{N}(0, 0.05)$	[−0.367,0.367]		
σ_z^2			$\mathcal{IG}(2.05, 0.011)$	[0.002,0.028]		
σ_g^2			$\mathcal{IG}(2.05, 0.011)$	[0.002,0.028]		
σ_c^2			$\mathcal{IG}(2.05, 0.011)$	[0.002,0.028]		
			COUNTRY–SPECIFIC PRIORS			
	MEXICO		**SOUTH AFRICA**		**TURKEY**	
$\sigma_{\epsilon_y}^2$	$\mathcal{IG}(2.00, 0.001)$	[0.000,0.002]	$\mathcal{IG}(2.00, 0.001)$	[0.000,0.002]	$\mathcal{IG}(2.00, 0.002)$	[0.000,0.006]
$\sigma_{\epsilon_c}^2$	$\mathcal{IG}(2.01, 0.003)$	[0.001,0.010]	$\mathcal{IG}(2.00, 0.002)$	[0.000,0.006]	$\mathcal{IG}(2.01, 0.004)$	[0.001,0.012]
$\sigma_{\epsilon_r}^2$	$\mathcal{IG}(2.00, 0.001)$	[0.000,0.002]	$\mathcal{IG}(2.00, 0.000)$	[0.000,0.000]	$\mathcal{IG}(2.00, 0.000)$	[0.000,0.001]
$\sigma_{\epsilon_e}^2$	$\mathcal{IG}(2.16, 0.021)$	[0.004,0.050]	$\mathcal{IG}(2.21, 0.025)$	[0.005,0.056]	$\mathcal{IG}(2.15, 0.020)$	[0.004,0.050]
	CANADA		**SWEDEN**		**SWITZERLAND**	
$\sigma_{\epsilon_y}^2$	$\mathcal{IG}(2.00, 0.001)$	[0.000,0.003]	$\mathcal{IG}(2.00, 0.001)$	[0.000,0.004]	$\mathcal{IG}(2.00, 0.001)$	[0.000,0.001]
$\sigma_{\epsilon_c}^2$	$\mathcal{IG}(2.00, 0.001)$	[0.000,0.002]	$\mathcal{IG}(2.00, 0.001)$	[0.000,0.003]	$\mathcal{IG}(2.00, 0.001)$	[0.000,0.001]
$\sigma_{\epsilon_r}^2$	$\mathcal{IG}(2.00, 0.000)$	[0.000,0.000]	$\mathcal{IG}(2.00, 0.000)$	[0.000,0.000]	$\mathcal{IG}(2.00, 0.000)$	[0.000,0.000]
$\sigma_{\epsilon_e}^2$	$\mathcal{IG}(2.02, 0.007)$	[0.001,0.019]	$\mathcal{IG}(2.00, 0.022)$	[0.005,0.062]	$\mathcal{IG}(2.24, 0.028)$	[0.005,0.060]

[24] This prior distribution implies a mean of 0.01 and variance of 0.002.

2.5 Estimation Results

This section discusses the estimation results for the six countries under investigation. First, we present the posterior distributions of our estimated parameters. Then, we run a “horse race” between the benchmark model and the liability dollarization setup with respect to their ability to capture the dynamics in our four observable variables.

2.5.1 Parameter Distributions

In the following, we focus on the estimation results concerning the structural part of the model. Table 2.5 displays the posterior distribution of the estimated structural parameters. A complete description of all estimated parameters, including those determining the off–model dynamics, can be found in the Appendix.

All results are based on 150,000 draws of which the initial 100,000 (125,000) draws were burned for EMEs (developed economies). We keep only every 25^{th} (10^{th}) draw for EMEs (developed economies) in order to avoid autocorrelation problems. Furthermore, we have performed a convergence test for each specification. Columns four and seven in Table 2.5 report the p–values of Geweke's χ^2–test (see Geweke 1992). We can never reject the null of convergence at conventional significance levels. Therefore, we are rather confident that our posterior distributions have converged.

Let us first consider the estimates of parameter ψ. We do not only find heterogeneity with respect to the choice of the model but also regarding the country group. What is striking is that ψ is considerably higher in the benchmark economy than in the model featuring foreign currency debt. Thus, once we introduce liability dollarization as a further form of capital market imperfections, the estimated debt–elasticity of interest rates becomes less pronounced.[25] This is particularly the case for the Mexican economy, where we observe an extreme discrepancy in ψ

[25] Admittedly, this finding is not very surprising. In the liability dollarization setup, variation in the interest rate can additionally be attributed to exchange rates fluctuations. Compare the interest rate rules in equations (2.13) and (2.23). Since real exchange rates in EMEs tend to be procyclical, volatility on the right–hand side of the interest rate rule unambiguously rises once we introduce liability dollarization, while it remains unchanged on the left–hand side such that factor ψ must decline.

Table 2.5: Posterior Distributions of Structural Parameters

	Posterior Median	Posterior 90% Bands	χ^2 Test	Posterior Median	Posterior 90% Bands	χ^2 Test
			Emerging Market Economies			
			Mexico			
		Benchmark			**Liability Dollarization**	
ψ	4.342	[3.315,4.885]	0.27	0.216	[0.0880,0.488]	0.96
ρ_z	0.622	[0.487,0.744]	0.58	0.708	[0.5741,0.828]	0.50
ρ_g	0.751	[0.637,0.845]	0.58	0.790	[0.6316,0.890]	0.26
ρ_c	0.689	[0.458,0.875]	0.37	0.547	[0.3648,0.726]	0.21
σ_z^2	0.034	[0.028,0.043]	0.91	0.036	[0.0289,0.044]	0.79
σ_g^2	0.040	[0.031,0.052]	0.26	0.029	[0.0213,0.039]	0.83
σ_c^2	0.128	[0.082,0.201]	0.89	0.189	[0.1056,0.370]	0.45
			South Africa			
		Benchmark			**Liability Dollarization**	
ψ	1.664	[1.115,2.668]	0.31	0.275	[0.1578,0.420]	0.93
ρ_z	0.918	[0.874,0.958]	0.50	0.782	[0.6795,0.863]	0.92
ρ_g	0.827	[0.767,0.886]	0.86	0.797	[0.6900,0.869]	0.95
ρ_c	0.626	[0.442,0.815]	0.43	0.654	[0.4663,0.798]	0.59
σ_z^2	0.015	[0.014,0.018]	0.85	0.020	[0.0172,0.023]	0.91
σ_g^2	0.012	[0.010,0.014]	0.22	0.016	[0.0123,0.021]	0.86
σ_c^2	0.082	[0.059,0.110]	0.34	0.086	[0.0579,0.137]	0.56
			Turkey			
		Benchmark			**Liability Dollarization**	
ψ	4.067	[2.743,4.830]	0.50	0.455	[0.1259,1.182]	0.86
ρ_z	0.691	[0.552,0.803]	0.25	0.648	[0.5124,0.763]	0.24
ρ_g	0.629	[0.508,0.741]	0.46	0.705	[0.5614,0.811]	0.10
ρ_c	0.646	[0.428,0.822]	0.49	0.507	[0.3384,0.655]	0.48
σ_z^2	0.062	[0.049,0.078]	0.87	0.059	[0.0455,0.075]	0.49
σ_g^2	0.080	[0.060,0.107]	0.14	0.074	[0.0528,0.101]	0.66
σ_c^2	0.201	[0.114,0.384]	0.12	0.192	[0.1026,0.428]	0.20
			Developed Economies			
		Canada			**Sweden**	
ψ	2.335	[1.646,3.573]	0.14	2.490	[1.486,4.103]	0.89
ρ_z	0.901	[0.852,0.948]	0.38	0.885	[0.829,0.939]	0.95
ρ_g	0.757	[0.676,0.832]	0.91	0.597	[0.488,0.706]	0.15
ρ_c	0.920	[0.860,0.958]	0.53	0.738	[0.523,0.878]	0.53
σ_z^2	0.013	[0.011,0.015]	0.70	0.022	[0.018,0.025]	0.46
σ_g^2	0.009	[0.008,0.011]	0.56	0.018	[0.015,0.022]	0.80
σ_c^2	0.047	[0.038,0.058]	0.88	0.074	[0.055,0.102]	0.55
		Switzerland				
ψ	0.165	[0.141,0.193]	0.54			
ρ_z	0.880	[0.826,0.931]	0.55			
ρ_g	0.596	[0.486,0.699]	0.52			
ρ_c	0.697	[0.515,0.835]	0.92			
σ_z^2	0.014	[0.013,0.016]	0.48			
σ_g^2	0.012	[0.010,0.014]	0.89			
σ_c^2	0.093	[0.067,0.129]	0.25			

Notes: Results are based on 150,000 draws from the posterior distribution of which for EMEs the first 100,000 and for developed economies the first 125,000 draws were burned. To avoid autocorrelation issues, we only keep every 10^{th} draw for developed economies, and every 25^{th} for EMEs. The χ^2 figure denotes the p–value of Geweke's χ^2–test for convergence (4% taper). Variances are reported in percentages.

across models. For instance, evaluated at the median of the posterior distribution, a slight increase in the external debt to income ratio of merely one percentage point lifts the cost of borrowing by as much as 4.34 percentage points in the benchmark economy, whereas in the extended model interest rates rise by only 0.22 percentage points. In light of this simple numerical exercise, the model with foreign currency debt seems to deliver debt–elasticities that are more reasonable in terms of their economic significance.

Looking at the benchmark economy, our estimation results suggest that the magnitude of reduced form financial frictions is more severe in EMEs than in developed economies. In fact, apart from South Africa, the mode of the posterior distribution of ψ obtained for EMEs is greater than its counterpart in the group of developed countries. In general, our findings for EMEs are to some extent consistent with the results reported by García-Cicco *et al.* (2010). On the one hand, our estimates for Mexico and Turkey in the benchmark model indicate a perceptibly higher debt–elasticity of the interest rate compared to their study's findings for Argentina. On the other hand, the elasticity obtained in the liability dollarization framework is lower for all three EMEs than the one documented by García-Cicco *et al.* (2010).

Turning to the parameters of the structural processes, we find that autocorrelation coefficients tend to be relatively high. This is especially the case for South Africa. By and large, however, we do not find large differences in the persistence parameters both across models and countries. For the group of emerging markets, the median of ρ_g, the parameter governing the persistence of the non–stationary productivity process, ranges from about 0.6 to 0.8. These estimates are clearly higher than those reported by Aguiar and Gopinath (2007) and García-Cicco *et al.* (2010). Nonetheless, they fall into the range of the results obtained by Chang and Fernández (2013) and Boz *et al.* (2011) for Mexico as well as Nguyen (2011) for the United States.

Interestingly, the variances of our structural shocks seem to differ between models and country groups. Estimated variances of the two technology processes are generally higher in EMEs than in advanced economies. Aguiar and Gopinath (2007) highlight the necessity of a high standard deviation of the permanent relative to transitory productivity shock in their model in order to account for certain business cycle phenomena in EMEs. In the benchmark model, we indeed find a higher ratio of volatilities $\frac{\sigma_g}{\sigma_z}$ for EMEs, except South Africa, than for developed economies. However, our estimation exercise suggests a much lower relative volatility of trend shocks in EMEs compared to Aguiar and Gopinath (2007).[26] What is more, we find that the ratio of standard deviations at the median of the posterior is even lower in the model with liability dollarization than in the benchmark model for Mexico and Turkey, while it is the same in both model versions for South Africa.[27] Nonetheless, as we will demonstrate in Section 2.6, our model with liability dollarization performs reasonably well in matching business cycle patterns in EMEs despite a relatively low $\frac{\sigma_g}{\sigma_z}$.

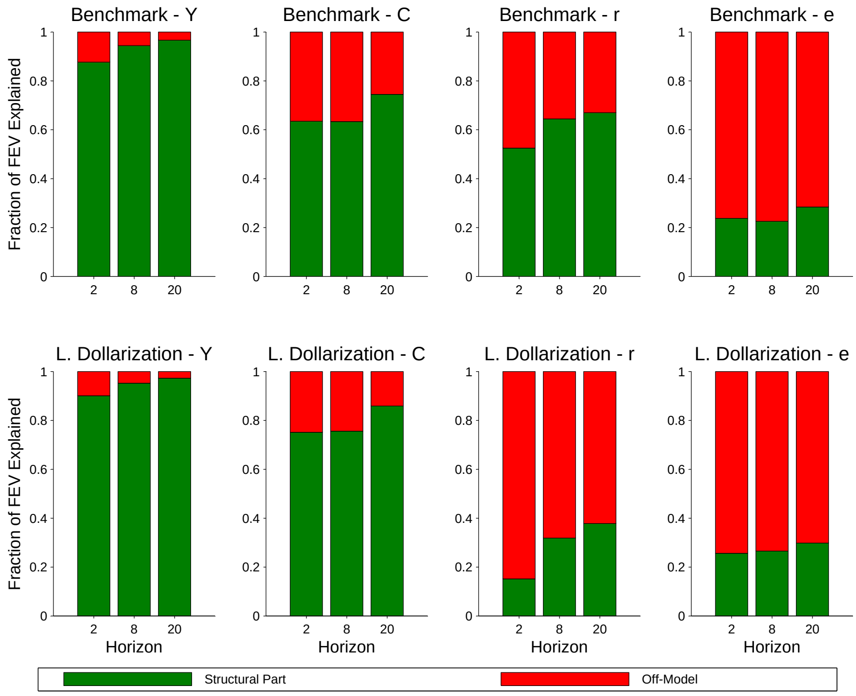
2.5.2 Model Fit

Next, we analyze the importance of the structural part relative to the off–model part in driving the dynamics of the observable variables. For this purpose, Figure 2.3 depicts the fraction of the forecast error variance attributed to structural shocks, i.e. permanent and transitory technology as well as foreign demand shocks, confronted to the fraction explained by the off–model dynamics. While evaluating the respective setup at the median of the posterior distribution, we compute the mean forecast error variance decomposition across all EMEs in both the benchmark economy and the model with liability dollarization. This allows us to study the extent to which our structural model is able to capture the dynamics in our observables. Hence, we can easily assess and compare the fit of our setups.

[26] Looking at the median of the posterior distributions, we calculate a ratio of volatilities $\frac{\sigma_g}{\sigma_z}$ equal to 0.8321, 0.9045, and 0.9258 for Canada, Sweden, and Switzerland, respectively. In the benchmark (liability dollarization) model, we get a ratio of 1.0847 (0.8975) for Mexico, 0.8944 (0.8944) for South Africa, and 1.1359 (1.1199) for Turkey. For a comparison, GMM estimates obtained by Aguiar and Gopinath (2007) imply ratios as high as 4.0189 for Mexico and as low as 0.7460 for Canada. To gauge the relative importance of trend shocks, these authors calculate the random walk component of the Solow residual, which also takes the persistence of shocks into account. The size of the random walk component in our estimation can be found in Appendix A.3.3.

[27] What is striking is that estimation results for South Africa are in various aspects different from those obtained for Mexico and Turkey. This peculiarity might be explained by the fact that in contrast do other emerging markets, South Africa has for decades had deep and well developed financial markets. Also, as pointed out by Eichengreen and Hausmann (2005), it is one of the few emerging markets, which traditionally has been able to issue bonds denoted in their own currency on international capital markets.

Figure 2.3: Forecast Error Variance Decomposition – Model Comparison



Notes: Mean forecast error variance decomposition across all EMEs. Results are based on median outcomes of the respective posterior distributions.

The graph reveals that the liability dollarization setup outperforms the benchmark model in accounting for the variation in output, consumption and real exchange rates at all forecast horizons. The superiority of the framework with liability dollarization is most perceivable for consumption. Yet we also observe that the benchmark model explains a larger portion of the variability in real interest rates. We explain this peculiar result for the real interest rate by a change in the importance of interest rate shocks once we augment the model with liability dollarization. Recall that both our models abstract from any exogenous disturbances in the interest rate like world interest rate or country premium shocks. Nonetheless, our estimation procedure implicitly controls for such interest rate shocks by the inclusion of a dynamic measurement error. In light of this interpretation, our exercise suggests that once countries can only borrow in foreign currency, interest rate shocks apparently become more important.[28] By and large, we therefore infer

[28]Neumeyer and Perri (2005), Uribe and Yue (2006), García-Cicco *et al.* (2010), and Chang and Fernández (2013) have augmented their SOE models with interest rate shocks. These authors stress the merits of this model extension for explaining macroeconomic fluctuations in emerging markets. In particular, Chang and Fernández (2013) show that interest rate shocks are amplified

that the model with liability dollarization fits the data in EMEs better than the benchmark setup.

Furthermore, estimation results are generally in strong favor of our theoretical framework. Though being quite stylized, the structural model performs very well, especially in capturing the dynamics of the main macroeconomic aggregates, i.e. output and consumption. Regarding exchange rates, we observe that only about 20 to 30 percent of the variation can be attributed to shocks characterized in the theoretical model. This finding is owed to the fact our models cannot produce such high volatilities in exchange rates we observe in the data.

2.6 Model Analysis

This section examines in how far our theoretical model helps us in understanding macroeconomic dynamics in emerging markets. As the previous section has demonstrated, the model with liability dollarization outperforms the benchmark setup in fitting the data. Hence, we confidently treat the liability dollarization framework as the more appropriate model for EMEs and focus on the analysis of the extended setup for this country group. For comparison, we analyze the benchmark model for EMEs in Appendix A.

We begin with implementing a forecast error variance decomposition to assess the relative importance of different shocks in explaining macroeconomic fluctuations. We then turn to an impulse response analysis of the three structural shocks in our liability dollarization setup. Subsequently, we compare model implied business cycle moments with their empirical counterparts to demonstrate that our model succeeds in replicating various stylized business cycle facts. Finally, we show the model's ability to account for the sudden stop in Mexico's capital inflows during the Tequila Crisis of 1994–1995.

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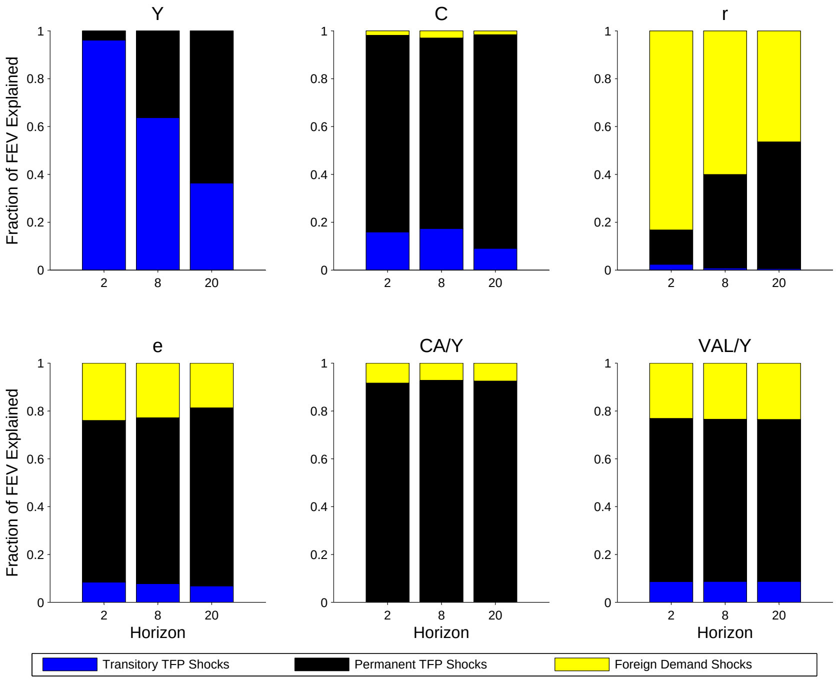
by financial frictions. This underpins our finding that the off–model dynamics of interest rates play a greater role in the setup with liability dollarization.

2.6.1 Forecast Error Variance Decomposition

In what follows, we study the relative contribution of various shocks in driving the dynamics in our theoretical economy. For this purpose, we perform a forecast error variance decomposition of the structural part of our model, evaluated at the median of the posterior distributions for each country.

Figure 2.4: Forecast Error Variance Decomposition – EMEs

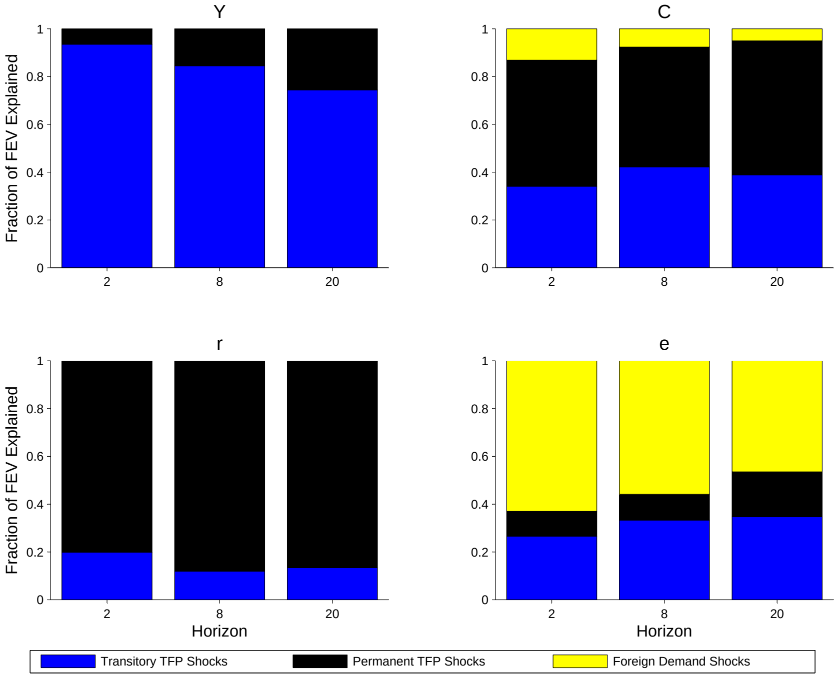


Notes: Mean forecast error variance decomposition across all EMEs for the model with liability dollarization. Results are based on median outcomes of the respective posterior distributions.

Figures 2.4 and 2.5 plot the average forecast error variance decomposition of selected variables across all EMEs and developed countries, respectively.[29] Certain patterns are worth emphasizing. First, in both emerging markets and developed countries, transitory shocks are the driving force behind output in the short–run. Looking at the developed world, we observe this particular feature not only in the short–run but also in the long–run. In EMEs, on the contrary, the permanent productivity process gains importance over longer horizons and eventually becomes the major determinant of output fluctuations in the long–run. Moreover, in both cohorts, trend shocks predominantly account for consumption

[29]Forecast error variance decompositions for all six countries, as well as for both models for the cohort of EMEs, can be found in Appendix A.4.

Figure 2.5: Forecast Error Variance Decomposition – Developed Economies



Notes: Mean forecast error variance decomposition across all developed countries. Results are based on median outcomes of the respective posterior distributions.

variation over all forecast horizons. But permanent shocks are relatively more important for consumption fluctuations in EMEs than in advanced economies.

Second, transitory technology disturbances generally play a minor role for the dynamics in the cost of borrowing. It is essentially growth shocks that account for interest rate variations in advanced countries. In EMEs, however, foreign demand shocks also seem to govern interest rate dynamics to a non–negligible extent, especially in the short–run. This finding indicates that changes in external demand may have important feedback effects on the interest rate in emerging markets.

Third, both transitory productivity and foreign demand disturbances explain a considerable share of the variation in the real exchange rate in industrialized economies. By contrast, it is permanent shocks that dominate relative international price movements in EMEs over all forecast horizons.

Finally, this predominance of trend shocks in emerging markets is even more striking if we look at the forecast error variance decomposition of the current account to output ratio. Figure 2.4 suggests that virtually all fluctuation in $\frac{CA}{Y}$ can be attributed to permanent productivity shocks. Similarly, more than 60 percent of the forecast error variance of the valuation effects to GDP ratio is determined by innovations to the non–stationary technology process. Foreign demand shocks account for about one third of the variation in $\frac{VAL}{Y}$, while the influence of transitory technology shocks again is trifling.

In a nutshell, our exercise suggests that transitory productivity shocks are far more important in explaining fluctuations of macroeconomic aggregates in industrialized countries compared to EMEs. As opposed to García-Cicco *et al.* (2010) and Chang and Fernández (2013), we conclude that even though we account for financial frictions in our model, both transitory and, above all, permanent disturbances play a role in explaining business cycle variations in EMEs. This in turn is concurrent with the findings of Aguiar and Gopinath (2007), who argue that macroeconomic fluctuations in EMEs are mainly driven by trend shocks. Thus, we largely find support for their famous hypothesis that *"the cycle is the trend"*.[30]

2.6.2 Impulse Response Analysis

Next, we shed more light on the mechanics of our model describing EMEs. To this end, we parametrize the liability dollarization setup at the median of the posterior distributions and compute impulse responses to the three structural shocks for each country.

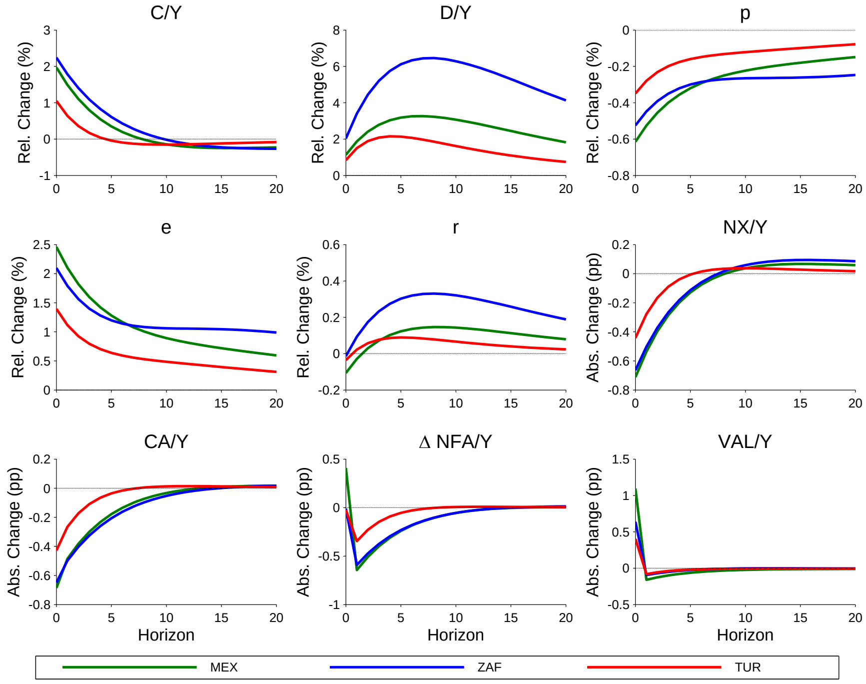
Permanent versus Transitory Productivity Shocks

Figures 2.6 and 2.7 plot selected impulse responses to a one percent permanent and transitory productivity disturbance, respectively.

A positive trend shock leads to an increase in consumption and foreign debt relative to income. On the contrary, the effects on $\frac{C}{Y}$ and $\frac{D}{Y}$ are reverse following a positive transitory shock. These opposite responses follow from the optimal

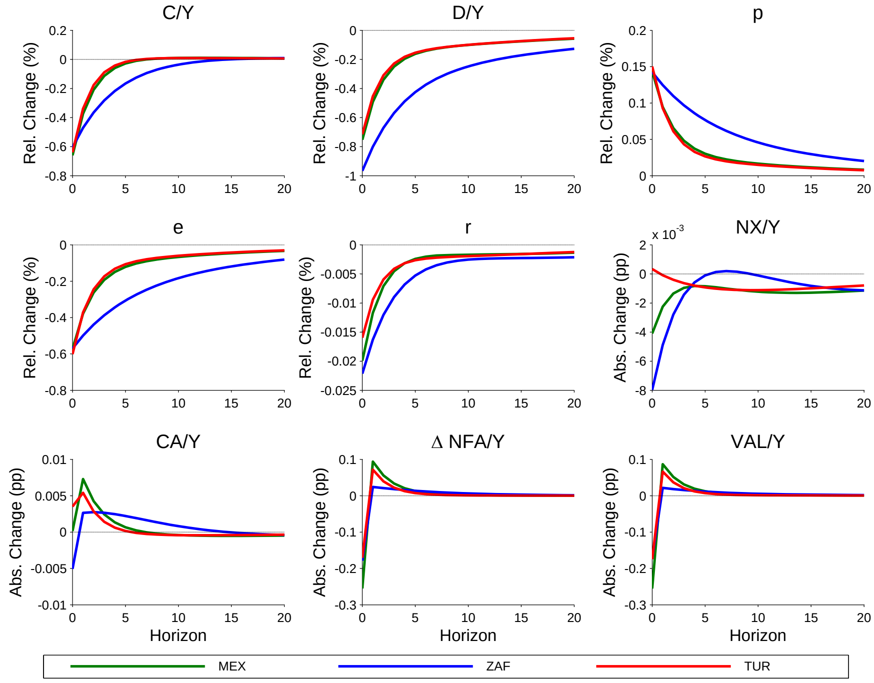
[30] In a recent study, Naoussi and Tripier (2013) estimate the framework of Aguiar and Gopinath (2007) for a number of developed, emerging markets, and developing economies. They find that permanent shocks are much more important in developing countries and emerging markets than in advanced economies. Therefore, their results corroborate the notion that *"the cycle is the trend"*, too.

Figure 2.6: Impulse Responses – Permanent Shock



Notes: Impulse responses to a one percent permanent productivity shock in the model with liability dollarization for all EMEs evaluated at the median of the respective posterior distribution.

Figure 2.7: Impulse Responses – Transitory Shock



Notes: Impulse responses to a one percent transitory productivity shock in the model with liability dollarization for all EMEs evaluated at the median of the respective posterior distribution.

savings behavior of the representative consumer and have the same interpretation as in the model of Aguiar and Gopinath (2007). After a positive growth shock, households do not only realize higher income today but also anticipate higher income in the future. The expectation of higher future income is due to the fact that (i) the positive impact on productivity is permanent and does not vanish over time, (ii) adjustment costs imply a gradual change in capital, and, (iii) in addition, growth shocks are persistent ($\rho_g > 0$). Since agents prefer a smooth consumption path over time, it is optimal to raise consumption by more than the initial increase in output. In fact, households borrow on international capital markets in order to finance their optimal consumption plan and additional investment, which explains the excess response of debt relative to GDP. In contrast, this consumption smoothing rationale also induces households to curb international borrowing, i.e. they save after a positive transitory shock, because income is expected to revert to its long–run equilibrium path in the future. As a result, consumption reacts less strongly than output such that $\frac{C}{Y}$ falls on impact.

A permanent shock also reduces the price of the composite consumption good p, whereas a temporary productivity innovation raises the price level. This can be explained as follows. Positive technology shocks lead to instantaneous jumps in income. As explained above, if shocks are permanent, people do not only benefit from higher income today but also anticipate even higher income in the future. Hence, households sharply raise their demand for home–produced goods (in form of consumption and investment) on impact. This increase in demand actually overshoots the initial rise in supply, which drives up the price of home–produced goods. As a consequence, the relative price of composite consumption expressed in terms of home–produced goods p falls. On the contrary, the initial increase in demand falls short of the one in supply after a transitory shock, such that the price of home–produced goods must decline in equilibrium and the relative price of total consumption p rises.

Due to imperfect substitutability between home and foreign goods the relative change of the domestic price of the foreign good p_F must always be stronger than the one of the price of the overall consumption index p. This follows immediately from the definition of the price index in equation (2.9). As a consequence, the real exchange rate in equation (2.14) appreciates (depreciates) following a positive trend (transitory) productivity shock.

The response of the real interest rate is in principle ambiguous. A higher expected debt to income ratio after a permanent shock puts an upward pressure on the interest rate. At the same time, however, the associated real appreciation reduces the debt burden, which dampens the increase in the interest rate. Interestingly, our results suggest that the real appreciation effect outweighs the debt to income ratio effect in the case of Mexico, while the effects largely offset each other in South Africa and Turkey. Regarding the reaction after a temporary productivity shock, we witness a fall in the real interest rate in all three countries.

Irrespective of its nature, a positive productivity shock induces households to consume more. Consequently, consumption of both home and foreign goods goes up, too. As described above, the price of foreign goods relative to home goods p_F falls after a positive trend shock. This means that the rest of the world experiences a real depreciation and thus demands less goods produced in the home country $c_H^\star$ (see equation (2.15)). In sum, the home country exports less while at the same time the value of its imports increases such that net exports decline. In contrast, domestic exports rise after a transitory shock because of a real appreciation abroad. Hence, the increase in both imports and exports leave the overall impact on the trade balance unclear. In our exercise at hand, these two counteracting effects largely cancel out such that we observe a rather weak response of the net exports to output ratio.

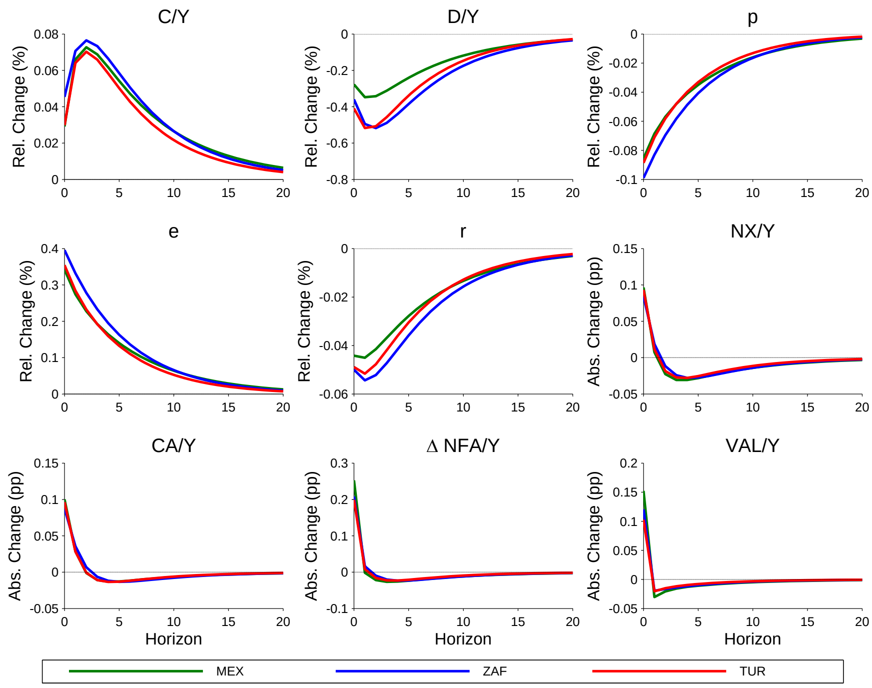
The deterioration of the trade balance together with higher interest payments on foreign debt translates into a worsening of the current account to income ratio after a trend shock. Furthermore, the associated real appreciation reduces the amount of outstanding foreign debt and therefore initially generates positive valuation effects (see equation (2.26)). The change in the net foreign asset position in (2.22) is given by the sum of the current account and valuation effects. As a result, positive valuation effects in fact dampen the negative change in foreign assets induced by the fall in the current account. In the case of Mexico, these valuation effects exceed the drop in the current account such that the value of net foreign assets actually goes up on impact.

The response of $\frac{CA}{Y}$ to a transitory shock is slightly positive in Mexico and Turkey, but negative in South Africa. In Mexico, for instance, the fall in interest payments on foreign debt obligations more than compensates the deterioration of the trade balance such that there is a positive reaction of the current account. Likewise, the real depreciation leads to negative valuation effects, which have a negative impact on the net foreign asset position. What is striking is that these external balance sheet effects are strong enough to generate a fall in net foreign assets in countries where we observe an initial increase in the current account, namely Mexico and Turkey.

Foreign Demand Shock

Figure 2.8 displays impulse responses to a one percent increase in foreign consumption. By and large, outcomes do not vary substantially across countries.

Figure 2.8: Impulse Responses – Foreign Demand Shock



Notes: Impulse responses to a one percent foreign demand shock in the model with liability dollarization for all EMEs evaluated at the median of the respective posterior distribution.

A positive shock to foreign consumption $c^\star$ directly translates into a rise in domestic exports $c_H^\star$. Consequently, net exports increase on impact. Furthermore, higher demand for domestically produced goods, *ceteris paribus*, puts an upward pressure on the price of home goods such that the relative prices of foreign goods p_F and composite consumption p fall. Since the relative drop in p_F prevails the decrease in p, the real exchange rate appreciates.

The favorable movement in the real exchange rate entails a positive wealth effect, which induces domestic households to consume more. As a matter of fact, the relative increase in consumption c is larger than the one in output y such that the consumption to GDP ratio rises.[31] Also, households substitute consumption of relatively more expensive home goods c_H for relatively cheaper foreign goods c_F. This somewhat dampens the positive reaction of the trade balance and explains its reversal in the periods after the shock.

In addition, the external debt to income ratio falls. Although consumption becomes cheaper, real appreciation drives up the price of consumption today expressed in units of consumption tomorrow (see equation (2.22)). Agents know that the demand shock is only temporary and anticipate a real depreciation in the future. Therefore, they have an incentive to save more, i.e they reduce their international debt holdings.[32] A lower $\frac{D}{Y}$, along with an appreciated real exchange rate, pushes down the real interest rate. The resulting cut in interest payments plus higher net exports lead to an increase in the current account, which in turn increases the domestic foreign asset position. Positive valuation effects, originated by real appreciation, eventually boost the improvement of the external balance sheet.

Stabilizing or Destabilizing Valuation Effects?

Our impulse response analysis illustrates that the impact of valuation effects on the net foreign asset position depends on the nature of the underlying shock. On the one hand, valuation effects mitigate the change in net foreign assets induced by the decline in the current account following a permanent productivity shock. Hence, they have a stabilizing impact on the external balance sheet in this case. On

[31] The increase in output initiated by higher foreign demand for home–produced goods is dampened by lower domestic absorption (i.e. lower domestic consumption of the home good and lower investment).

[32] We can think of domestic households investing in foreign goods by reducing the amount of international debt. In other words, they go long in foreign goods.

the other hand, valuation effects amplify the influence of the current account on net foreign assets after a foreign demand shock. Regarding transitory technology shocks, the effect is generally unclear. In our exercise, transitory productivity shocks entail external balance sheet effects that counteract the reaction of the current account in Mexico and Turkey, but reinforce it in South Africa. Having said this, our findings conflict with the implications of the model of Nguyen (2011), which predicts stabilizing (amplifying) valuation effects after a transitory (permanent) technology shock.

2.6.3 Business Cycle Moments

In this subsection, we gauge our structural model's ability to reproduce various business cycle patterns. To this end, we simulate the respective model evaluated at the median of the posterior distributions for each country. We generate data covering a time span of 100 periods and subsequently compute various moments based on the detrended series of our variables. On the whole, we repeat this exercise 5,000 times. Table 2.6 compares empirical moments with their model generated counterparts, which correspond to the median across all simulations. Empirical moments are calculated using quarterly real data from the IFS, apart from those involving valuation effects for which only annual data from Lane and Milesi-Ferretti (2007) are available. All series, except for the net exports to output ratio and valuation effects, have been logged, seasonally adjusted and filtered using the HP filter with smoothing parameter 1,600.

Consistent with the data, the model predicts generally higher standard deviations of income, consumption, and the net exports to output ratio in EMEs than in advanced economies. Hence, our theoretical economy can well account for the empirical regularity that macroeconomic fluctuations are more severe in emerging markets as compared to developed countries.

Furthermore, the model is not only able to generate excess volatility in consumption relative to output in EMEs, but also matches relative consumption volatilities in advanced countries quite well. This observation raises the question of why? On the one hand, as shown in Section 2.6.1, our estimation results suggest that macroeconomic dynamics in EMEs are predominantly driven by the non–stationary productivity component. On the other hand, the preceding subsection has demonstrated that consumption overshoots output after a permanent technology shock. It is the interplay of these two features that explains the excess volatility of consumption.

Table 2.6: Business Cycle Moments

	Data	Model	Data	Model	Data	Model
			Emerging Market Economies			
	Mexico		**S. Africa**		**Turkey**	
$\sigma(Y)$	2.42	5.31	1.60	4.25	3.70	6.30
$\sigma(C)$	3.68	6.71	2.46	5.08	5.72	7.65
$\sigma(NX/Y)$	6.63	1.58	4.04	0.95	3.42	1.46
$\sigma(e)$	9.63	7.71	8.70	5.05	9.54	7.47
$\sigma(C)/\sigma(Y)$	1.52	1.57	1.54	1.41	1.55	1.45
$\rho(NX/Y, Y)$	−0.17	−0.10	−0.40	−0.19	−0.56	−0.27
$\rho(e, NX/Y)$	−0.31	−0.62	−0.12	−0.43	−0.45	−0.48
$\rho((NX/Y)_t, (NX/Y)_{t-1})$	0.97	0.69	0.85	0.67	0.84	0.57
$\rho((VAL/Y)_t, (CA/Y)_t)$	−0.58	−0.34	−0.75	−0.30	−0.05	−0.38
$\rho((VAL/Y)_t, e_t)$	0.45	0.29	−0.31	0.28	0.19	0.30
			Developed Economies			
	Canada		**Sweden**		**Switzerland**	
$\sigma(Y)$	1.42	4.13	1.75	4.57	1.76	3.68
$\sigma(C)$	1.36	4.12	1.51	4.00	1.44	3.11
$\sigma(NX/Y)$	1.96	0.54	2.77	0.45	3.74	0.65
$\sigma(e)$	3.41	5.34	8.81	4.61	7.94	5.53
$\sigma(C)/\sigma(Y)$	0.96	1.00	0.86	0.77	0.82	0.71
$\rho(NX/Y, Y)$	0.01	−0.36	−0.01	−0.39	−0.17	0.27
$\rho(e, NX/Y)$	−0.03	−0.21	−0.07	−0.14	−0.02	−0.59
$\rho((NX/Y)_t, (NX/Y)_{t-1})$	0.93	0.28	0.94	0.15	0.84	0.49

Notes: Standard deviations are expressed in percentages except for the model implied standard deviation of the net exports to output ratio, which is expressed in percentage points. Empirical moments are calculated using quarterly data taken from the IFS, apart from those involving valuation effects for which only annual data from Lane and Milesi-Ferretti (2007) are available. All series, except for the net exports over output ratio and valuation effects, are real per capita variables, have been logged, seasonally adjusted and filtered using the HP filter with smoothing parameter $\lambda = 1,600$. Theoretical moments are based on sample moments of model generated data. For the group of EMEs, we have used the liability dollarization framework. Each theoretical economy is simulated 5,000 times with a sample size of 100. Median outcomes are reported.

Our model also succeeds in generating a negative correlation between the net exports to GDP ratio and income in EMEs. Yet it struggles to match this moment from a quantitative point of view. In fact, the model understates the countercyclicality of the net exports to output ratio in EMEs, but it also overstates this countercyclicality for the cohort of advanced economies, except Switzerland. Recall that permanent technology shocks induce households to purchase more foreign goods, while the real depreciation experienced by the rest of the world cuts the external demand for home goods. This leads to a deterioration of the home country's trade balance and explains why our model generates a negative correlation between the net exports to GDP ratio and income. The fact that we cannot replicate the high degree of countercyclicality of $\frac{NX}{Y}$ in EMEs is due to the relatively persistent non–stationary productivity process. Indeed, the higher the autocorrelation of the permanent technology process, the weaker the countercyclicality of the trade balance. As a matter of fact, if trend shocks are persistent enough, the income effect on labor supply induces households to work less after a positive permanent shock. In this scenario, output falls, which actually implies a positive correlation between income and net exports.[33]

Our model suggests that real exchange rates are in general more volatile in EMEs than in developed economies. This prediction is in line with what we observe in the data. Furthermore, the model reproduces the negative correlation between the real exchange rate and the net exports to output ratio in EMEs. In contrast, the benchmark model has difficulties in replicating the weak relationship between these two variables in the group of industrialized countries.

A key contribution of the paper by García-Cicco *et al.* (2010) is that their model can account for the empirically observed downward sloping autocorrelation function of $\frac{NX}{Y}$. Interestingly, our benchmark model exhibits a fairly low first–order serial correlation of the net exports to income ratio in developed economies, whereas the liability dollarization setup matches this moment better for EMEs. As García-Cicco *et al.* (2010) point out, it is important to allow for a ψ that is significantly different from zero in order to obtain a falling autocorrelation function of $\frac{NX}{Y}$. The reason for that is as follows. For instance, after a positive permanent shock, households increase their international debt holdings and run a trade balance deficit. In case of a high debt–elasticity ψ, the rise in debt relative to GDP

[33]Accordingly, our model's weak performance regarding the countercyclicality of the trade balance might be explained by our preference specification. As we have already mentioned in Section 2.3, our choice of Cobb–Douglas period utility implies an income effect on labor supply. In contrast, other researchers in this strand of the literature use GHH preferences, which do not feature income effects on labor supply.

in turn raises the real interest rate. This induces households to consume less and save more, which leads to an improvement of the trade balance. On the other hand, if ψ is close to zero (as for example in the calibration of Aguiar and Gopinath 2007) the feedback effect of changes in $\frac{D}{Y}$ on the cost of borrowing is virtually shut down, which results in an autocorrelation function of $\frac{NX}{Y}$ that resembles a near unit root process. In fact, our estimates of ψ in the benchmark economy are quite high compared to our liability dollarization framework. This might help us to explain why the model understates the first–order autocorrelation of $\frac{NX}{Y}$, especially for advanced economies.

Table 2.6 also provides meaningful insights with respect to the role of valuation effects in EMEs. Not surprisingly, they are positively correlated with the real exchange rate in our model. This feature is consistent with our descriptive findings for Mexico and Turkey. More importantly, our model predicts a negative relationship between valuation effects and the current account in all three EMEs. As a matter of fact, this is line with the negative correlation between $\frac{VAL}{Y}$ and $\frac{CA}{Y}$ in the data, especially for Mexico and South Africa. Consequently, we find that, on average, valuation effects have a stabilizing impact on the net foreign asset position. In light of our discussion in Section 2.6.2, this outcome can be explained by the fact that EMEs are predominantly exposed to trend shocks.

2.6.4 Mexico's Tequila Crisis

Finally, we investigate the performance of our model in crisis times. Over the last two decades, many EMEs have experienced severe balance of payments (BOP) crises, such as Mexico during the Tequila crisis of 1994–1995; Indonesia, Korea, Malaysia, the Philippines, and Thailand during the Asian crisis of 1997; or Argentina in 2001. A typical feature of BOP crises in emerging markets is the sudden stop in capital inflows, which usually brings about a reversal in current accounts and net exports, a drop in output, consumption, and investment, as well as exchange rate depreciations (see Mendoza 2010).

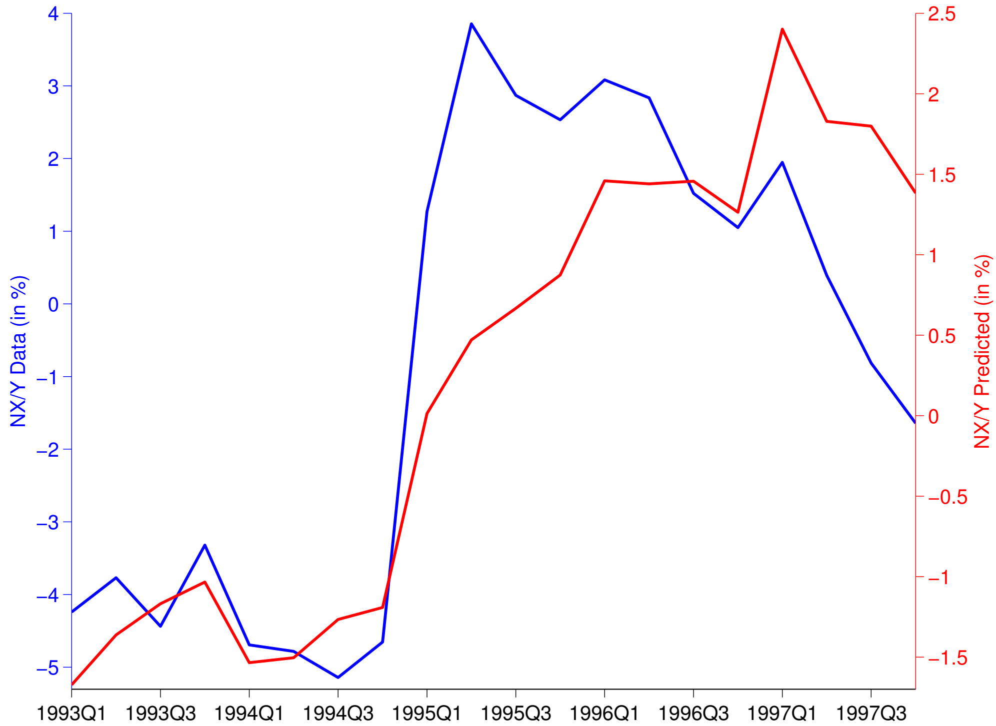
In what follows, we examine whether our theoretical framework is capable of replicating Mexico's sudden stop during the Tequila Crisis of 1994–1995. To do so, we adopt a similar approach as in Aguiar and Gopinath (2007). We calibrate our liability dollarization model at the median of the posterior distributions for Mexico. We use data on output, consumption, real interest rates, and real exchange rates and implement the Kalman filter to generate the unobservable state variables. Subsequently, we feed the obtained states into the model to compute time series for our control variables.

Figure 2.9 shows the true and predicted net exports to output ratio in Mexico between 1993Q1 and 1997Q4. As is evident from the figure, our model can reproduce the reversal in the Mexican trade balance between 1994 and 1995. At a first glance, however, our model seems to struggle to quantitatively match the dramatic change in $\frac{NX}{Y}$. It predicts an increase in the net exports to output ratio by 2.2 percentage points between the third quarter of 1994 and the second quarter of 1995, whereas the actual net exports to output ratio increased by as much as 7.7 percentage points. Note, however, that the steady state level of the trade balance to GDP ratio is much lower than its empirical counterpart.[34] If we look at the change of $\frac{NX}{Y}$ relative to its long–run mean rather than the absolute change, we actually find that our model performs quite well also from a quantitative point of view.

The remaining question is then why does our framework succeed in explaining the sudden stop in capital flows. The shock series produced by the Kalman filter indicate that the Mexican economy was hit by a strong negative permanent shock in the fourth quarter of 1994. As we have discussed in Section 2.6.2, a negative trend shock leads to an increase in the net exports to output ratio. In addition, a large negative permanent shock causes a sharp fall in output and consumption, as well as a real depreciation, which is also in line with what we observe in the data. What is more, our liability dollarization model suggests that sudden stops are associated with negative valuation effects. As a result, balance sheet effects actually dampened the increase in Mexico's net foreign asset position during the Tequila crisis according to the model.

[34] Recall from Section 2.4.2 that we do not pin down the steady state net exports to output ratio in our calibration exercise.

Figure 2.9: Mexico's Tequila Crisis of 1994–1995



Notes: Actual versus predicted net exports to output ratio for the Mexican economy between the first quarter of 1993 and the fourth quarter of 1997.

2.7 Conclusion

We develop a small open economy DSGE model featuring a non–stationary productivity process, differentiated home and foreign goods, and endogenous exchange rate movements to study the importance of financial frictions and trend shocks in explaining macroeconomic dynamics in EMEs. We also extend our benchmark setup and introduce liability dollarization as a special form of financial market distortions in emerging markets. This model modification allows us to analyze the impact of valuation effects on the external balance sheet in these countries.

In the empirical part of the paper, we estimate our model using Bayesian techniques for a group of EMEs. Furthermore, in order to investigate the difference between emerging and advanced economies, we perform our estimation exercise also for a group of developed countries. We account for off–model dynamics by allowing for a (vector–)autoregressive measurement error in our estimation procedure. As a matter of fact, this constitutes to a novel approach in this strand of the literature.

Our results show that the co–existence of financial frictions and trend shocks helps to explain macroeconomic dynamics in EMEs. In particular, incorporating liability dollarization in our framework improves the model fit. Our analysis suggests that trend shocks are the driving force behind macroeconomic fluctuations in EMEs. Therefore, we find support for the famous hypothesis that *"the cycle is the trend"*, even though we include financial market distortions in our setup.

Our liability dollarization model succeeds in replicating certain stylized facts about emerging market business cycles: (i) it predicts more severe macroeconomic fluctuations in EMEs than in developed countries, (ii) it matches the excess volatility of consumption relative to output, (iii) it qualitatively reproduces the countercyclicality of the net exports to output ratio, although it falls short to match this moment on a quantitative basis, and (iv) it can replicate the sudden stop of capital inflows during the Mexican Tequila Crisis between 1994 and 1995. Interestingly, our liability dollarization framework suggests that valuation effects on average have a stabilizing impact on the net foreign asset position in EMEs. In this vein, we also contribute to a currently active line of research on external balance sheet effects, which so far has mainly focused on developed economies.

Admittedly, the introduction of liability dollarization as a from of financial frictions in our model is fairly simple. One could go one step further and study the implications liability dollarization in the presence of other credit market distortions. In particular, we could build on the literature on credit frictions in macroeconomics (see Kiyotaki and Moore 1997, Bernanke *et al.* 1999) and incorporate collateral constraints in the model. In that case, the amount of debt depends on the agent's net worth, which is subject to exchange rate variations due to liability dollarization. It would then be interesting to see how the combination of amplification effects, resulting from the imposition of collateral constraints, and liability dollarization affects macroeconomic dynamics in EMEs.

Chapter 3

A Small Open Economy in the Great Depression: the Case of Switzerland

3.1 Introduction

Recent research has shown that Switzerland's dismal performance during the 1930s was mainly due to its exchange rate policy (Bordo *et al.*, 2007; Bordo and James, 2007). Thanks to a high gold cover ratio, the Swiss National Bank was able to defend the old parity against any speculative attack, thus preventing an early devaluation of the Swiss franc that would have restored the competitiveness of Switzerland's exporting sectors. This exchange rate policy was motivated by a variety of reasons, yet the widespread gold standard mentality certainly played a key role. The strong belief that a devaluation would lead to inflation and that the gold standard was the only reliable guarantee for prosperity and stability, led economies to stay on gold as long as possible – a decision which implied a lagged recovery from the Great Depression (e.g. Balderston, 2003; Feinstein *et al.*, 2008).[1] As (Straumann, 2010, p. 129–142) shows, this was also the case for Switzerland. Only when the last major trading partner, France (see Table 3.1), decided to devalue its currency, Switzerland was ready to change course. In September 1936, the Swiss franc was devalued by 30 percent.

[1]"*A further aspect of great significance was the widespread belief in financial and political circles that it was essential to return to the pre–war gold standard if the growth and prosperity of the pre–1914 era were to be re–established, whatever the sacrifices their countries would have to make in oder to force down wages and prices so that the pre–war value of the currency could be restored.*" (Feinstein *et al.*, 2008, p. 1)

To demonstrate the consequence of Switzerland's defense of the gold standard, we adapt the famous "contracting spiral of world trade"–graph, first published by the Austrian Institute for Business Cycle Research (*Österreichisches Institut für Konjunkturforschung*) in 1933 (Eichengreen and Irwin, 1995), to Swiss exports (Figure 3.1). Real exports fell by 50 percent until June 1932, followed by a weak recovery to about 60–70 percent of the October 1929 level. The consequence of the decision to join the Gold Bloc in 1933 (together with Belgium, France, Italy, the Netherlands, and Poland) was that exports stayed at this level until end of 1936. Due to the overvalued Swiss franc, the Swiss exporting sectors profited less from the recovery of the world economy than small European countries with a devalued currency such as the Scandinavian countries.

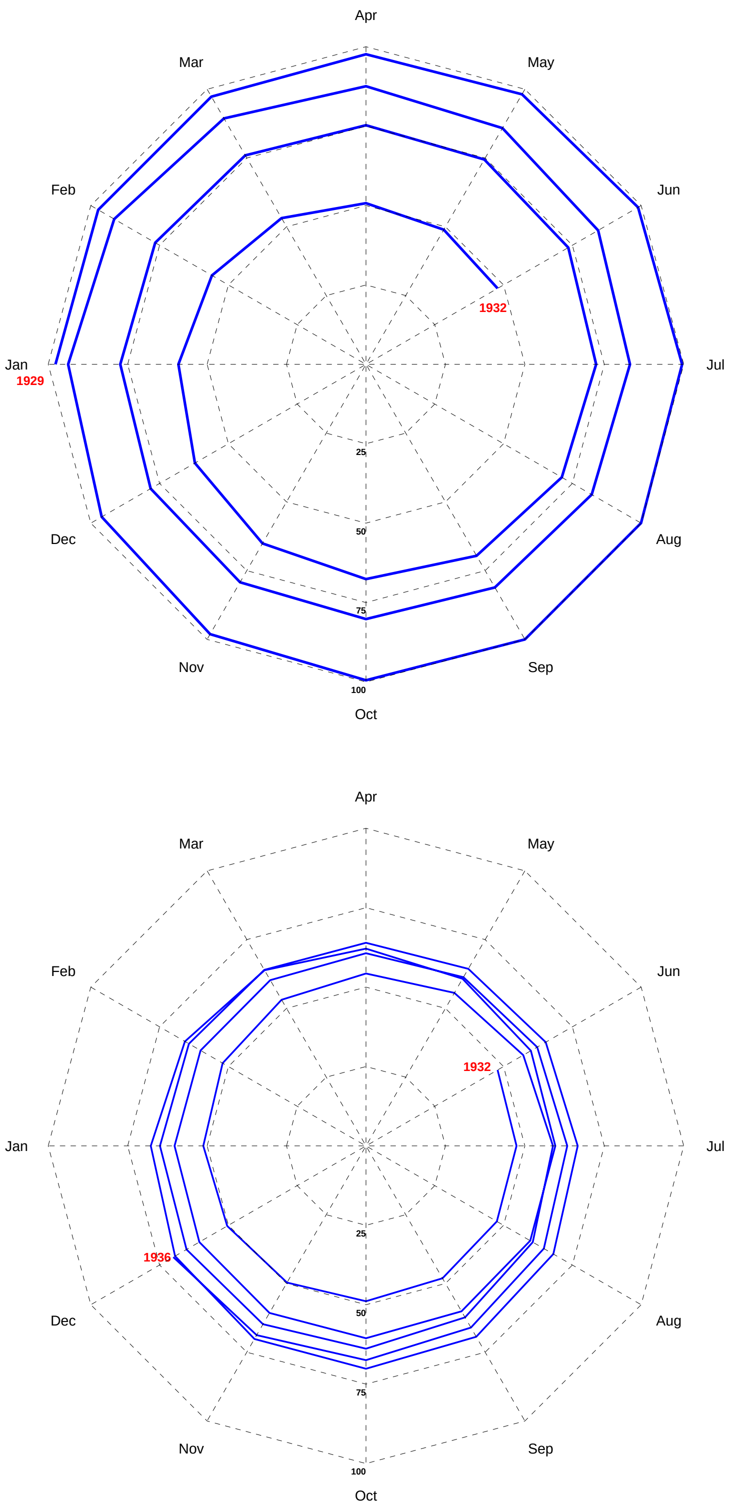
Table 3.1: Major Trading Partners of Switzerland in the Interwar Period

County	Export Share	Import Share
Germany	17.43%	27.25%
France	13.09%	16.15%
Italy	8.22%	7.62%
United Kingdom	12.19%	5.53%
United States	7.24%	6.57%
Total	58.18%	63.12%

Notes: Average country shares of total exports and imports during 1929–1936. Source: Swiss Economic and Social History Online Database (`www.fsw.uzh.ch/hstat`), Tables L.18, L.19, L.22 ,L.23.

The Swiss National Bank's defense of the old gold parity was particularly detrimental as Switzerland's prices were extraordinarily sticky during this period. As a matter of fact, regulations protecting individual economic sectors and fixing prices dramatically increased during the crisis. Instead of enabling the downward adjustment, the government sought to cushion the negative effects of an overvalued currency by containing competition. Almost any pressure group, in particular Swiss farmers, was able to obtain protection and subsidies. In many historical accounts, the rise of these corporatist policies in the 1930s has been hailed as the beginning of a fruitful cooperation between capital and labor. But in the context of an orthodox gold standard policy, these rigidities proved to be fatal. Therefore, understanding the nature of Switzerland's economic crisis during the

Figure 3.1: Swiss Exports, January 1929 – December 1936



Notes: Real exports, October 1929=100; Source: *Monatsstatistik des auswärtigen Handels der Schweiz*, 1929–1932

1930s requires not only a thorough analysis of the exchange rate policy, but also a better grasp of how prices adjusted before and after 1929.

Besides the exchange rate policy and the stickiness of prices, there is a third feature defining the course of Switzerland's economic crisis. The ample gold reserves may have prevented the Swiss National Bank from leaving the gold standard at an early state of the crisis. But on the other hand, they also allowed the central bank to refrain from increasing interest rates in the face of speculative attacks. From 1931 to 1936 when the devaluation enabled the central bank to reflate the economy nominal interests remained close to zero. By contrast, Belgium and France, which also defended the gold standard until the mid–1930s were forced to increase their interest rates whenever investors mistrusted their currencies. Thus, the usual constraints of the gold standard did not apply until 1936 for the case of Switzerland.

In this paper, we try to account for these different aspects of the Swiss crisis. Our contribution is threefold. First, we provide a new monthly dataset covering the performance of the real economy from January 1926 to December 1938. Second, we estimate the structural parameters of a New Keynesian small open economy model for Switzerland in the spirit of Clarida *et al.* (2000, 2001) and Galí and Monacelli (2005), going beyond the calibration exercise in Bordo *et al.* (2007). We explicitly take into account the fact that Switzerland was not forced to increase nominal interest rates during the Gold Bloc period due to the massive gold inflow starting with the German crisis in June 1931 and intensifying after Britain went off gold. Following Ireland (2004), the model incorporates a vector autoregressive measurement error component capturing the dynamics in the data which are not represented by the economic part. This feature allows to assess the model's suitability for the data under analysis. Moreover, it is possible to compare the relative importance of the structural shocks (foreign demand shock and terms of trade shock) with the contribution of the measurement error block by looking at the decomposition of the forecast error variance. The results show that the economic part of the model contributes a significant variance share. The structural approach enables us to embark on a counterfactual experiment by simulating the Swiss economy in the case of a devaluation of the Swiss franc in September 1931, the month at which the UK left gold.

Our results show that the terms of trade shock played an important role for the Swiss economy during the Interwar Period. While foreign demand was recovering after 1932, the terms of trade further deteriorated. Consequently, the latter effect dominated the foreign demand impulse and led to a long lasting recession, which only ended when Switzerland left gold in September 1936. As a result, our counterfactual analysis implies that in case of an earlier devaluation of the Swiss franc, the economy would have recovered a lot faster and reached its steady state level shortly after leaving gold: the decision to defend the parity turned out to be extremely costly. This finding is in line with the successful recovery of Sweden after leaving gold together with the UK (Rathke *et al.*, 2011).

Our third contribution is that we provide a thorough discussion of how prices behaved from 1926 to 1938. In particular, we detect severe price rigidities, induced by a high degree of cartelization and regulatory measures, as an important characteristic of the Swiss economy in the Interwar Period. Moreover, our estimation results not only confirm this finding but also emphasize the cost of it. A counterfactual analysis shows that a lower degree of price stickiness would have been beneficial for the Swiss economy. This result highlights the potential benefits of an internal devaluation and the cost of corporatist policies.

The remainder of the paper is organized as follows. Section 3.2 motivates and outlines the underlying model. In Section 3.3 we present the data and our estimation strategy. Section 3.4 discussed the results and Section 3.5 concludes.

3.2 The Model

The underlying model corresponds to the basic New Keynesian small open economy model as introduced by Galí and Monacelli (2005) and Galí (2008). Already in the Interwar years, the Swiss economy was characterized by a high degree of openness.[2] Thus, we believe it is important to model open economy characteristics explicitly. Moreover, we follow Calvo (1983) by modeling nominal price rigidities. This seems to be an important stylized fact for the period under analy-

[2] E.g. in 1928 exports accounted for 20 percent of GDP (Source: *Die Volkswirtschaft*, 1924–1944).

sis: a large share of domestic prices and wages was fixed by the government. Not only did it own the national monopoly for mail, telegram and telephone services and the Swiss federal railway, but also began to stabilize agricultural prices in the midst of the depression (Rutz, 1970, p. 180–184).

Price rigidities became an issue already in the 1920s, illustrated by the increasing difference between wholesale and consumer prices after the recession of 1921/22 (Kaufmann 1952, Marbach 1952, p. 747; see upper part of Figure 3.4). Especially the degree of cartelization of the Swiss economy was blamed for this development.[3] Regional monthly prices for important consumption goods provide an impression of price stickiness in the 1920s. The data on regional prices cover the period 1924–1929.[4] From 33 municipalities,[5] the most frequent prices per month are reported for 15 consumption goods,[6] which amounts to a total of 495 time series. Counting the frequency of monthly price changes in these price series reveals a very low modus of 0.07, which is depicted in Figure 3.2.

The regional variation is not very high (25% quantile: 0.080; 50% quantile: 0.090; 75% quantile: 0.110; Figure 3.3), suggesting that price stickiness was a

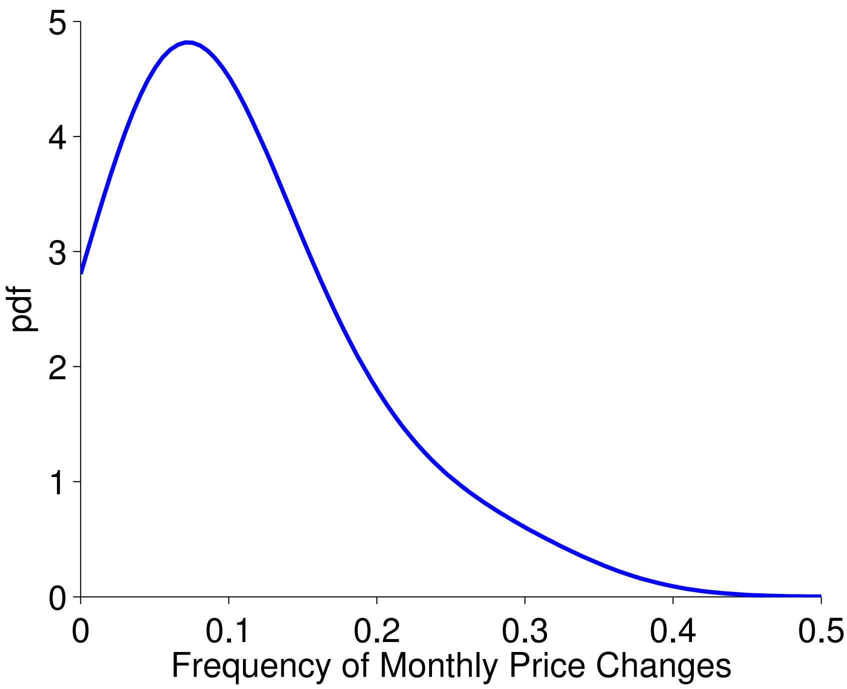
[3]Commenting on the first results of the cartel enquête of the *Preisbildungskommission* in 1937, Fritz Marbach, a member of the commission from 1931 to 1965 and president from 1939 on, stated that free pricing was the exception rather than the rule ("[...] *im allgemeinen darf man aber wohl behaupten, dass der Kartellpreis und nicht der 'freie Preis' die Regel ist*"; Marbach 1937, p. 34). He repeats this assessment in his overview article on cartels in the 1955 edition of the *Handbuch der Schweizerischen Volkswirtschaft* ("*Der freie Preis ist in der schweizerischen Wirtschaft eine Aussnahme.*" Marbach, 1955, p. 19). The stability of cartelization in Switzerland can be explained by the attitude of the public (see Katzenstein 1985, 2003 and the discussion in Straumann 2010, p. 344–345 for the importance of democratic corporatism for European small open economies). Illustrating this phenomenon, Marbach joked that the Swiss are in principle in favor of free markets, under the condition that they are exempt ("*Der Schweizer ist dem Prinzip des freien Wettbewerbes (allerdings nimmt er sich dabei nur allzuleicht selber aus) im grossen und ganzen recht gewogen.*" Marbach, 1952, p. 754). For an overview of cartelization in Switzerland, see Eidgenössisches Volkswirtschaftsdepartement (1957) and Schröter (2011).

[4]For 1924 to 1927, they come from the *Sozialstatistische Mitteilungen*, edited by the *Eidg. Arbeits–amt*. After 1927, the source is the *Wirtschaftliche und sozialstatistische Mitteilungen*, edited by the *Eidg. Volkswirtschaftsdepartement*.

[5]Aarau, Arbon, Baden, Basle, Berne, Biel, La Chaux–de–Fonds, Chur, Frauenfeld, Fribourg, Geneva, Glarus , Herisau, Langenthal, Lausanne, Liestal, Le Locle, Lugano, Luzern, Neuchâtel, Olten, Porrentruy, Rorschach, St. Gall, St–Imier, St. Moritz, Schaffhausen, Schwyz, Sion, Solothurn, Vevey, Winterthur, Zurich, Zug. We take these municipalities as representative for the respective canton (Figure 3.3).

[6]Beef (*Ochsenfleisch mit Knochen, zum Sieden*), pork (*frisches mageres Schweinefleisch mit Knochen*), veal (*Kalbsfleisch, 1. Qualität mit Knochen*), fat (*inländisches Schweineschmalz, frisches Nierenfett*), butter (*Tafelbutter*), cheese (*Emmentaler–, Greyerzer– oder Appenzellerkäse, 1. Qualität*), milk (*Vollmilch*), bread (*Vollbrot*), flour (*Weissmehl*), pasta (*offene Teigwaren, Mittelqualität*), sugar (*Kristallzucker weiss*), potatoes (*neue inländische Kartoffeln*), eggs (*inländische Trinkeier*), coal (*Braunkohlenbriketts, ins Haus geliefert*).

Figure 3.2: Price Stickiness, 1924–1929



Notes: Gaussian kernel density estimator, bandwidth: (Pagan and Ullah, 1999, equation 2.50); data sources: see text.

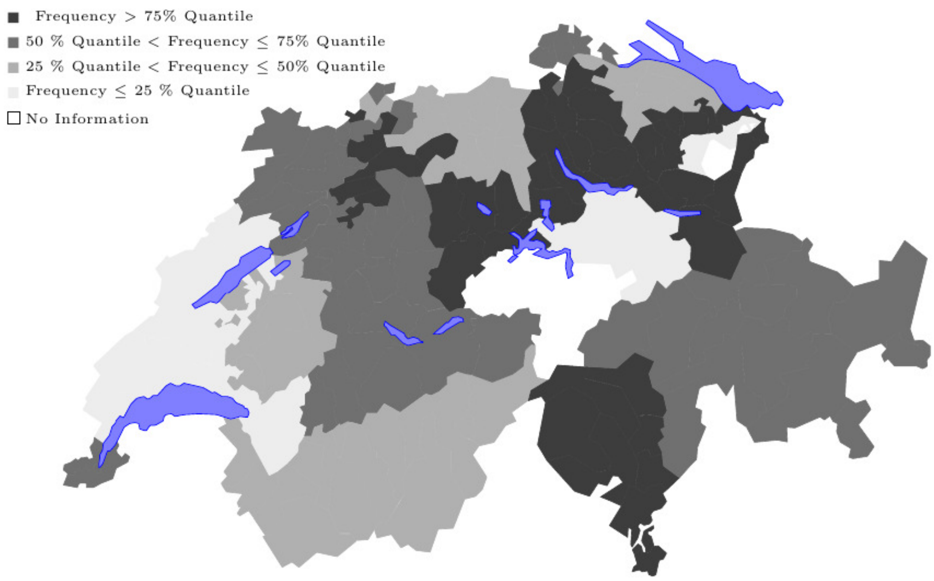
regionally wide spread phenomenon. The cantons with a low degree of price stickiness as compared to the rest are Zurich, St. Gall, Lucerne, Solothurn, and Ticino, ranging from the alpine South to the industrialized North–West of Switzerland.

In order to address the issue, the ministry of economics (*Eid. Volkswirtschaftsdepartement, EVD*) installed a new committee to study price formation (*Preisbildungskommission*) in 1926, but without any control rights.[7]

A department for price controls (*Preiskontrollstelle*) was founded in 1931, in response to the Great Depression. Its main purpose was to monitor the influence of import restrictions on prices and to prevent *unjustified* price increases. In the beginning, it lacked effectiveness, because it depended heavily on voluntary cooperation. The lower part of Figure 3.4 illustrates this lack of effectiveness: wholesale prices kept falling faster than consumer prices. As a consequence and in fear of inflationary pressure due to the devaluation of the Swiss franc in September

[7]For the following, see Lautner (1950, p. 1–12), Eidgenössische Zentralstelle für Kriegswirtschaft (1950, p. 877–887), and Marbach (1952).

Figure 3.3: Regional Price Stickiness, 1924–1929



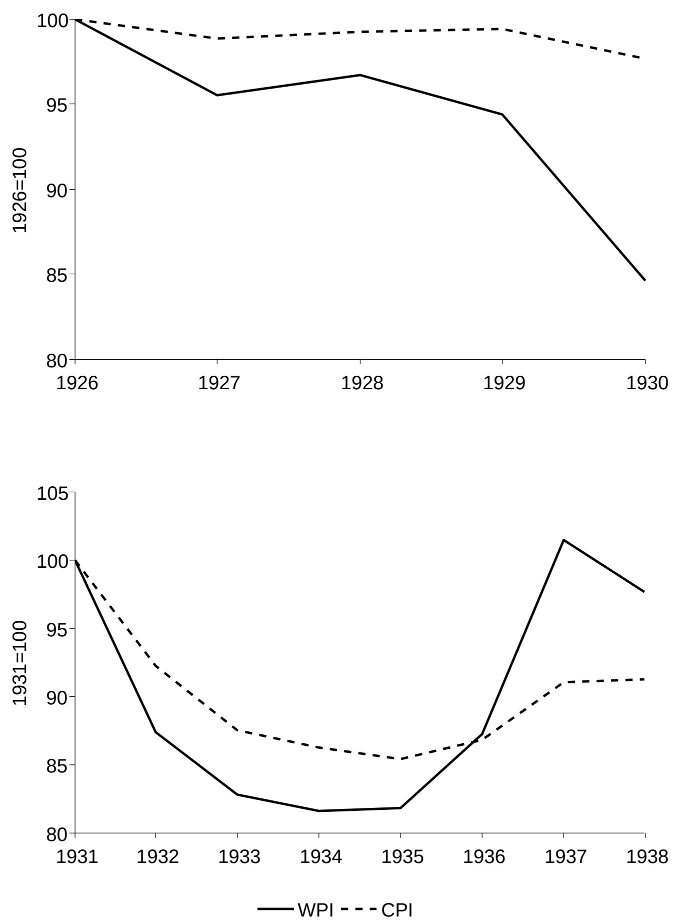
Notes: Frequency of monthly price changes; 33 municipalities, 15 prices (179 potential changes; data sources: see text); 25% quantile: 0.080; 50% quantile: 0.090; 75% quantile: 0.110. There are no prices available for Central Switzerland cantons such as Uri and Obwalden/Nidwalden, and also for Appenzell Innerrhoden.

1936, the Swiss parliament decided to implement direct price controls in 1936. The *Preiskontrollstelle* was authorized to collect necessary data and regulate prices. These regulations had two purposes: to protect consumers against unjustified price increases, and also to protect producers from price dumping. For example, milk prices were pegged by compulsory cartels and quotas, and export of watches became only possible conditional to complying with the price regulations of the watch industry (Hug, 1938, p. 364–366). Almost all prices were regulated (goods and services, gas, electricity, rents), and from September 1936 on, could only be increased with official approval, and even with approval, the adjustment had to be stepwise (Hug, 1938, p. 362). The effectiveness of this regulatory intervention can be seen from the lower part of Figure 3.4: while wholesale prices started to increase steeply after 1936, the increase in consumer prices was only moderate. In 1950, the central office for war economics (*Eidgenössische Zentralstelle für Kriegswirtschaft*) reported overall success: due to the interventions, consumer prices adjusted much slower in the period 1939–1946 than in 1914–1921, when there was no intervention (Eidgenössische Zentralstelle für Kriegswirtschaft, 1950, p. 898).

Lastly, as stated in the introduction, we do not include a gold standard mechanism. To motivate our choice of model, we follow Bernanke (1995) and decompose Swiss money supply ($M1$) in the period 1922–1936 into contributions of the money multiplier ($M1/BASE$, $BASE$: monetary base), the inverse of the gold backing ratio ($BASE/RES$; RES: international reserves), the ratio of international reserves to gold ($RES/GOLD$), and the gold reserves of the Swiss National Bank, expressed in domestic currency ($GOLD = PGOLD \times QGOLD$):

$$M1 = \frac{M1}{BASE} \times \frac{BASE}{RES} \times \frac{RES}{GOLD} \times PGOLD \times QGOLD \tag{3.1}$$

Figure 3.4: Producer and Consumer Price Indices, 1926–1938



Source: Swiss Economic and Social History Online Database (`www.fsw.uzh.ch/hstat/`), Table H.1

The results reported in Table 3.2 and Figure 3.5 indicate that Switzerland did not fully commit to the *rules of the game* of the Gold Standard during the Interwar

Period: the ratio of the monetary base to international reserves ($BASE/RES$) is not stable and hence the cover ratio was significantly varying over time. In fact, it went up from 78 percent in 1925 to almost 100 percent in 1931. Consequently, an inflow of international currency reserves and gold reserves did not fully translate into an increase of the monetary base proportional to the cover ratio. Therefore, we refrain from including a particular Gold Standard mechanism into the model as opposed to e.g. Bordo *et al.* (2007).

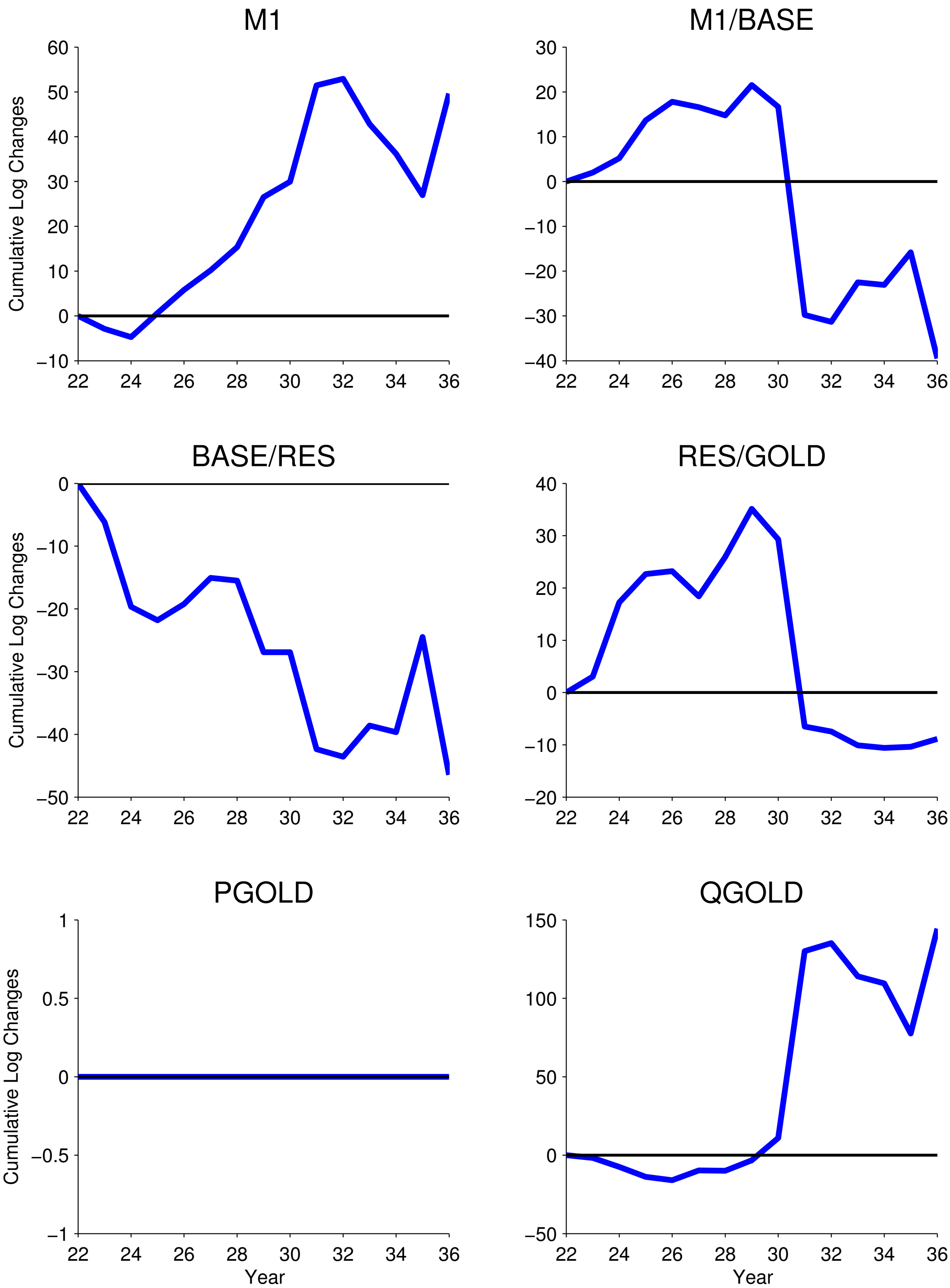
Table 3.2: Decomposition of Swiss Money Supply, 1922–1936

Year	$M1$	$\frac{M1}{BASE}$	$\frac{BASE}{RES}$	$\frac{RES}{GOLD}$	$PGOLD$	$QGOLD$	$\frac{RES}{BASE}$
1922	2395	2.10	1.60	1.12	3.44	186.00	0.62
1923	2327	2.14	1.50	1.15	3.44	182.76	0.66
1924	2285	2.21	1.31	1.33	3.44	172.63	0.76
1925	2411	2.41	1.29	1.40	3.44	161.95	0.78
1926	2538	2.51	1.32	1.41	3.44	158.51	0.76
1927	2652	2.48	1.38	1.34	3.44	168.79	0.73
1928	2792	2.43	1.37	1.45	3.44	168.48	0.73
1929	3122	2.60	1.22	1.59	3.44	180.04	0.82
1930	3232	2.48	1.22	1.50	3.44	207.51	0.82
1931	4006	1.56	1.05	1.05	3.44	683.12	0.95
1932	4066	1.53	1.04	1.04	3.44	719.30	0.97
1933	3675	1.68	1.09	1.01	3.44	581.59	0.92
1934	3439	1.67	1.08	1.00	3.44	555.89	0.93
1935	3136	1.79	1.25	1.01	3.44	404.24	0.80
1936	3934	1.41	1.01	1.02	3.44	788.52	0.99

Notes: M1, the monetary base (BASE), the gold reserves (GOLD), and the total reserves (RES) are measured in millions of Swiss francs. The gold parity (PGOLD) corresponds to the price of one gram of gold in Swiss francs. QGOLD denotes the quantity of gold reserves in tons.
Source: Swiss National Bank
`www.snb.ch/n/mmr/reference/histz_gm/source` (T1.3 and T2.2)
`www.snb.ch/n/mmr/reference/histz_snb/source (T1.1)`
`www.snb.ch/en/mmr/reference/histz_snb_book/source` (page 31)

Ultimately, we would like to assess whether an overvalued currency or the worldwide economic downturn was the main determinant of the long lasting recession in Switzerland. Consequently, we model both terms of trade and foreign demand as exogenous structural shocks. Using the dynamic stochastic general equilibrium approach allows to measure over–/undervaluation of the Swiss franc and to conduct counterfactual analysis in a straightforward way. Furthermore, we study the role of price rigidities and its importance during the Interwar Period

Figure 3.5: Decomposition of Swiss Money Supply, 1922–1936



Source: Swiss National Bank, see Table 3.2 for further detail.

in Switzerland. Therefore, we allow for monopolistic competition and nominal rigidities. The home economy is infinitesimal small and does not affect the economy of the rest of the world, and markets are assumed to be complete, i.e. agents trade a full set of state contingent bonds. In every period, economic agents form rational expectations, the representative household maximizes expected lifetime utility, and firms maximize expected profits. A sketch of the model is depicted in

Figure 3.6: Model Overview

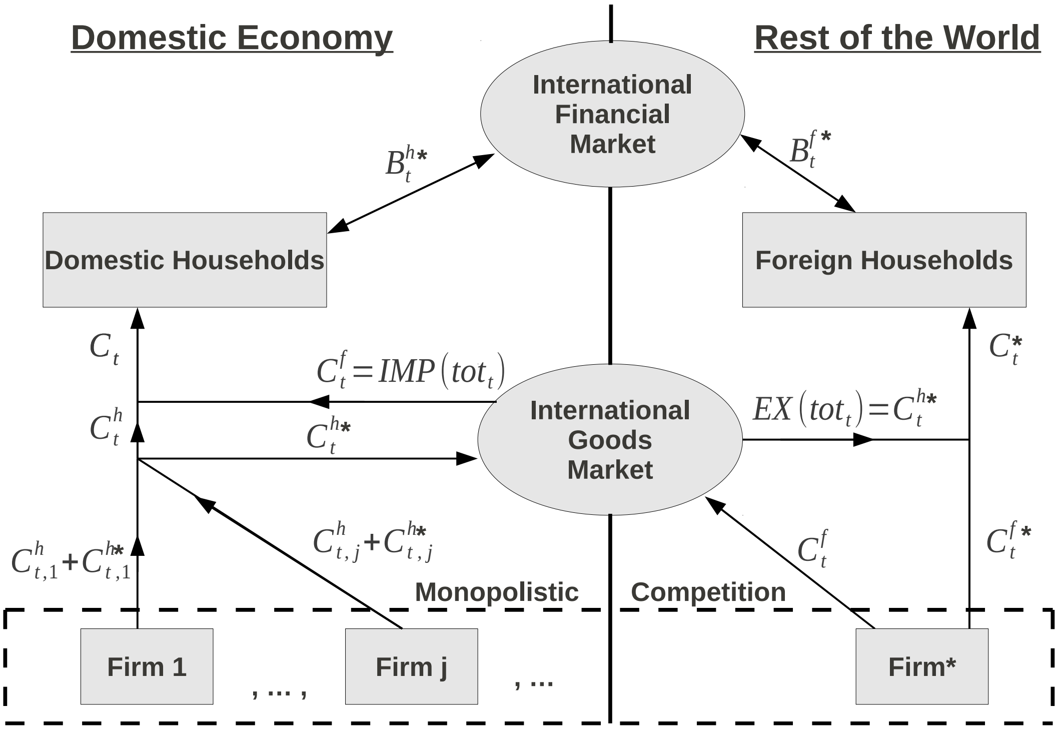


Figure 3.6, while more detailed description of the model, which corresponds to a basic New Open Economy Model, is presented below.

3.2.1 Households

The economy is populated by an infinitely lived representative household who seeks to maximize

$$\mathrm{E}_0\left[\sum_{t=0}^{\infty}\beta^t U(C_t, N_t)\right] \quad \text{with} \quad U(C_t, N_t) = \left(\frac{C_t^{1-\sigma}}{1-\sigma} - \frac{N_t^{1+\eta}}{1+\eta}\right)$$

by optimally choosing consumption C_t and labor input N_t. Its period t budget constraint looks as follows:

$$P_t C_t + Q_t B_{t+1} = W_t N_t + B_t, \tag{3.2}$$

where Q_t denotes the price of a one–period discount bond paying off one unit of domestic currency at time $t+1$, $\mathrm{E}_t\left[Q_{t,t+1}\right] \equiv Q_t = \frac{1}{R_t}$. P_t, B_t, W_t, σ, η, and β denote the consumer price index, bond holdings, the nominal wage, the inverse of the elasticity of substitution, the inverse of the wage elasticity of labor supply, and the discount factor respectively. Moreover, we impose a standard no–Ponzi condition, $\lim_{j\to\infty}\mathrm{E}_t\left[\frac{B_{t+\tau}}{\prod_{j=0}^{\tau} R_{t+j}}\right] = 0$, which implies that the period budget constraint always holds with equality. C_t denotes a consumption composite index, i.e.

$$C_t = \left((1-\gamma)^{\frac{1}{a}}\left(C_t^h\right)^{\frac{a-1}{a}} + \gamma^{\frac{1}{a}}\left(C_t^f\right)^{\frac{a-1}{a}}\right)^{\frac{a}{a-1}}, \tag{3.3}$$

where C_t^f refers to one single foreign good, $C_t^h \equiv \left(\int_0^1 \left(C_{t,j}^h\right)^{\frac{\theta}{\theta-1}} \mathrm{d}j\right)^{\frac{\theta}{\theta-1}}$ corresponds to a Dixit–Stiglitz Constant Elasticity of Substitution (CES) aggregate of domestic goods, and $C_{t,j}^h$ a domestic variety j. The exact composition C_t^h and C_t^f is optimally chosen by the households according to the demand functions

$$C_t^h = \left(\frac{P_t^h}{P_t}\right)^{-a} C_t(1-\gamma) \quad ; \quad C_t^f = \left(\frac{P_t^f}{P_t}\right)^{-a} C_t\gamma. \tag{3.4}$$

Moreover, P_t^f captures the foreign price of the foreign produced good, the preference parameter $\gamma \in [0,1]$ represents a measure of home bias,[8] $a > 0$ governs

[8]Since it is equal to the import share, it can also be interpreted as a natural measure of openness (Galí, 2008).

the substitutability between domestic and foreign goods, and $\theta > 0$ denotes the elasticity of substitution between domestic varieties. The household's utility maximization problem at period t can be summarized as

$$\max_{\{C_\tau, N_\tau, B_{\tau+1}\}} \mathrm{E}_t \left[\sum_{\tau=t}^{\infty} \beta^{\tau-t} \left(\frac{C_\tau^{1-\sigma}}{1-\sigma} - \frac{N_\tau^{1+\eta}}{1+\eta} \right) \right]$$
$$\text{s.t.} \quad P_\tau C_\tau + Q_\tau B_{\tau+1} \leq W_\tau N_\tau + B_\tau, \tag{3.5}$$

yielding the following two standard optimality conditions:

$$\frac{N_t^\eta}{C_t^{-\sigma}} = \frac{W_t}{P_t}; \tag{3.6}$$

$$\mathrm{E}_t \left[Q_{t,t+1} \right] = Q_t = \beta \mathrm{E}_t \left[\left(\frac{C_{t+1}}{C_t} \right)^{-\sigma} \left(\frac{P_t}{P_{t+1}} \right) \right]. \tag{3.7}$$

Equation (3.6) captures optimal static labor supply decision, i.e. marginal rate of substitution between labor and leisure is equal to the real wage rate, while the inter–temporal Euler equation is represented by equation (3.7).

3.2.2 Firms

Firm j produces output $Y_{t,j}$ using the production technology

$$Y_{t,j} = N_{t,j}, \tag{3.8}$$

with labor as the only input factor. Profits are maximized by minimizing costs for a given amount of output, i.e.

$$\min_{\{N_{t,j}\}} \frac{W_t}{P_t^h} N_{t,j}, \qquad \text{s.t.} \qquad Y_{t,j} = N_{t,j}. \tag{3.9}$$

The resulting first order condition contains the real marginal costs of production, which is denoted by Ψ_t. Since marginal costs are constant, Ψ_t is also equal to the real average cost or real unit cost of production:

$$\frac{W_t}{P_t^h} - \Psi_t = 0 \Leftrightarrow \Psi_t = \frac{W_t}{P_t^h} = W_t^r. \tag{3.10}$$

In equilibrium, goods market clearing implies

$$Y_t = C_t^h + C_t^{h\star}, \tag{3.11}$$

which implies that aggregate output Y_t is fully absorbed by domestic consumption of the domestically produced good C_t^h and foreign consumption of the domestic good $C_t^{h\star}$. This leads to the demand functions for variety j,

$$C_{t,j}^h + C_{t,j}^{h\star} = \left(\frac{P_{t,j}^h}{P_t^h}\right)^{-\theta} Y_t. \tag{3.12}$$

$P_{t,j}^h$ denotes the price of domestic variety j, and P_t^h corresponds to the price index of domestic goods.

Prices are sticky in the sense that with a probability ω firms are not allowed to optimally update their price at the beginning of the period. As stated above, price stickiness is an important stylized fact for the period under analysis: a large share of domestic prices and wages was fixed by the government. The pricing mechanism used here goes back to Calvo (1983). $\bar{P}_{t,j}^h$ denotes the price set by firm j in period t, which implies $P(P_{t+\tau,j}^h = \bar{P}_{t,j}^h) = \omega^\tau$. Moreover, since all firms are identical and face identical demand curves, $\bar{P}_{t,j}^h = \bar{P}_t^h$.

Therefore, period t profit of firm j, conditional on being allowed to reset its price is

$$\pi_{t,j} = \left(\bar{P}_t^h - P_t^h \Psi_t\right)(C_{t,j}^h + C_{t,j}^{h\star}) = \left(\bar{P}_t^h - P_t^h \Psi_t\right)\left(\frac{\bar{P}_t^h}{P_t^h}\right)^{-\theta} Y_t, \tag{3.13}$$

where $P_t^h \Psi_t$ corresponds to the nominal unit costs. Conditional on being allowed to reset its price level, firm j maximizes the expected current market value of profits while the price remains effective. In particular,

$$\max_{\{\bar{P}_t^h\}} \quad \mathrm{E}_t\left[\sum_{\tau=0}^{\infty} \omega^\tau Q_{t,t+\tau}\left(\bar{P}_t^h - P_{t+\tau}^h \Psi_{t+\tau}\right)\left(\frac{\bar{P}_t^h}{P_{t+\tau}^h}\right)^{-\theta} Y_{t+\tau}\right], \tag{3.14}$$

where $Q_{t,t+\tau} = \beta^\tau \frac{\Lambda_{t+\tau}}{\Lambda_t}$ denotes the stochastic discount factor for nominal payoffs.

The first order condition with respect to $\bar{P}^h_t$ is

$$\mathrm{E}_t\left[\sum_{\tau=0}^{\infty}\omega^{\tau}Q_{t,t+\tau}\frac{\Lambda_{t+\tau}}{\Lambda_t}Y_{t+\tau}\left((1-\theta)\left(\frac{\bar{P}^h_t}{P^h_{t+\tau}}\right)^{-\theta}+\theta\left(\frac{\bar{P}^h_t}{P^h_{t+\tau}}\right)^{-\theta-1}\Psi_{t+\tau}\right)\right]=0. \tag{3.15}$$

3.2.3 Global Characteristics

Exchange Rate & Terms of Trade

We assume that the law of one price holds, i.e.

$$P^f_t = S_t P^\star_t, \tag{3.16}$$

where $P^\star_t$, P^f_t, S_t denote the foreign price of the foreign produced good denoted in foreign currency, the foreign price of the foreign produced good denoted in domestic currency, and the nominal exchange rate, expressed as the price of foreign currency in terms of domestic currency respectively. The real exchange rate is

$$\Phi_t = \frac{P^f_t}{P_t} = \frac{S_t P^\star_t}{P_t}, \tag{3.17}$$

and corresponds to the price of a foreign good in terms of domestic consumption bundles, while the terms of trade, the price of a foreign good in terms of domestic goods, is defined as

$$\Delta_t = \frac{P^f_t}{P^h_t} = \frac{S_t P^\star_t}{P^h_t}, \tag{3.18}$$

and follows an exogenous[9] and stationary first–order autoregressive (AR(1)) process in logs,

$$\ln(\Delta_t) = \rho_\delta \ln(\Delta_{t-1}) + \epsilon^\delta_t, \qquad \epsilon^\delta_t \sim N(0,\sigma^2_\delta), \tag{3.19}$$

where $\rho_\delta < 1$ characterizes the persistence parameter and σ^2_δ the variance of the shock ϵ^δ_t.

[9] We are aware of the fact that this specification is not fully consistent with the underlying model, because prices are endogenously determined. Lubik and Schorfheide (2007) point out that an estimation of the full structural model including endogenous terms of trade turned out to be too restrictive and therefore lead to implausible estimates. Consequently, we decided to to follow Lubik and Schorfheide (2007) by treating the terms of trade as an exogenous process.

Foreign Country

The domestic economy is an infinitesimal small open economy whereas the foreign economy can be thought of as an aggregate of infinitely many identical infinitesimal small open economies. Therefore, in the aggregate, net exports of all foreign economies will sum up to zero, which implies $C_t^\star = Y_t^\star$. Foreign consumption $C_t^\star$ is equal to foreign demand $Y_t^\star$, which follows an exogenous and stationary AR(1) process in logs,

$$\ln(Y_t^\star) = (1-\rho_\star)\ln(Y^\star) + \rho_\star \ln(Y_{t-1}^\star) + \epsilon_t^\star, \quad \epsilon_t^\star \sim N(0, \sigma_{y^\star}^2), \tag{3.20}$$

with a persistence parameter $\rho_\star$ smaller than one and a variance $\sigma_{y^\star}^2$ of the shock $\epsilon_t^\star$.

International Trade

Exports are denoted in domestic goods and given by

$$EX_t = C_t^{h\star}. \tag{3.21}$$

For imports (denoted in domestic goods), we have

$$IM_t = \frac{P_t^f}{P_t^h} C_t^f \tag{3.22}$$

Net exports (denoted in domestic goods) are the difference between exports and imports,

$$NX_t = EX_t - IM_t. \tag{3.23}$$

International Risk Sharing

International risk sharing under complete markets implies that the stochastic discount factor among different countries is equal to (Chari *et al.*, 2002b)

$$Q_{t,t+1} = \beta\left(\frac{C_{t+1}}{C_t}\right)^{-\sigma}\frac{P_t}{P_{t+1}} = \beta\left(\frac{C_{t+1}^\star}{C_t^\star}\right)^{-\sigma}\frac{S_t P_t^\star}{S_{t+1}P_{t+1}^\star}, \tag{3.24}$$

where $P_t^\star$ denotes the foreign consumer price index, and which implies the following international risk sharing condition:[10]

$$\left(\frac{C_t^\star}{C_t}\right)^{-\sigma} = \Phi_t. \tag{3.25}$$

As a result, complete markets lead to this this simple relationship linking the real exchange rate to the ratio of the marginal utilities of consumption of domestic and foreign households.

3.2.4 Market Clearing and Aggregate Production Function

The firm level production function is represented by

$$N_{t,j} = Y_{t,j}. \tag{3.26}$$

Labor market clearing implies

$$N_t = \int_0^1 N_{t,j} \mathrm{d}j, \tag{3.27}$$

which enables us to compute the aggregate production function

$$\begin{aligned} N_t &= \int_0^1 Y_{t,j} \mathrm{d}j = \int_0^1 \left(\frac{P_{t,j}^h}{P_t^h}\right)^{-\theta} \left(C_t^h + C_t^{h\star}\right) \mathrm{d}j = \\ &= Y_t \underbrace{\int_0^1 \left(\frac{P_{t,j}^h}{P_t^h}\right)^{-\theta} \mathrm{d}j}_{\zeta_t} = Y_t \zeta_t \qquad \Leftrightarrow \\ Y_t &= \frac{N_t}{\zeta_t}. \end{aligned} \tag{3.28}$$

ζ_t can be seen as a measrure of price dispersion. The full set of optimality conditions can be found in Appendix B.1.

[10] $\left(\frac{C_t^\star}{C_t}\right)^{-\sigma} = \underbrace{\left(\frac{C_0^\star}{C_0}\right)^{-\sigma} \frac{1}{\Phi_0}}_{\mu} \Phi_t = \mu \Phi_t$ represents the general form of the risk sharing condition. Without loss of generality we set the initial condition μ equal to one.

3.3 Data and Estimation Method

For the estimation exercise, we use monthly data of industrial production, inflation, and net exports, ranging from January 1926 to December 1938. An official industrial production index is not available before 1965 (Cascioni, 2000, p. 281). Already in the 1930s, this situation was deemed unsatisfactory, at least from the viewpoint of the Federal Statistical Office.[11] The problem of the missing Swiss production index (*Das Problem einer schweizerischen Produktionsstatistik*) was discussed at the 1936 meeting of the the Swiss Statistical Society (*Schweizerische Statistische Gesellschaft*). The overview in the *Statistisches Handbuch der Weltwirtschaft* published by the German statistical office in 1936 (Statistisches Reichsamt, 1936) showed that of the 80 countries in the collection, 54 had industrial production statistics, Switzerland not being among them. To explain the situation, industrial representatives (building, engineering, textile and printing) listed the general reluctance of the industry providing the data,[12] the high cost of data collection, and the availability of high quality trade statistics, which sufficed the needs of the mainly export oriented Swiss industry, therefore making a production index superfluous.[13] Because of the lack of contemporaneous data, we could switch to the sectoral estimates provided by David (1995), but these series are only at an annual frequency. Therefore, we decided to use the business cycle indicators published in the period of interest as a proxy, and take SBB (Swiss Federal Railway) freight data, as well as indicators for silk and watch production,[14] which represent the two most important export industries in Switzerland in the Interwar Period.[15]

Inflation data is calculated based on the consumer price index taken from the Federal Statistical Office.[16] Based on household accounts from 1912, 1920, and 1921 for skilled laborers, unskilled laborers and employees, the index was

[11] "*Ein grosser Teil der schweizerischen Bevölkerung ist auf Gedeih und Verderb auf den Ertrag der industriellen Anlagen und auf ihre Beschäftigung in ihnen angewiesen. Wie gross ist dieser Ertrag? Wir kennen ihn nicht.*" (Schwarz, 1936, p. 147)

[12] "*Dann muss die Verbandsleitung auch mit einer Abneigung der Mitglieder rechnen, Dinge bekannt–zugeben, welche die Grundlagen des Geschäfts betreffen. Diese Einstellung wäre besonders seitens der welschen Mitglieder zu gegenwärtigen, welche sich schon heute über einen angeblich überwuchernden 'esprit de police' der Verbände beklagen.*" (Marti, 1936, p. 176)

[13] See the contributions by Cattani (1936), Bühler-Krayer (1936), Fischer (1936), and Marti (1936).

[14] Source: SNB monthly reports (1926–1929, 1936–1938) and *Die Volkswirtschaft* (1930–1936).

[15] See Figure B.1 in Appendix B.2 for a time series of of the export shares of the two industries.

[16] Landesindex für Konsumentenpreise, `www.statistik.admin.ch` (cc-d-05.02.17.xls).

first published in January 1922 by the Federal Office of Labour (*Eidgenössisches Arbeitsamt*), first only for food. Because of critique by employee organizations and trade unions, it was extended to other expenditure groups and, after the revision in 1926, consisted of food, fuel (soap), clothing and rent.[17]

As already mentioned, there are high quality trade statistics available for Switzerland, both by volume and value, at monthly frequency.[18] The Federal Customs Office (*Eidgenössische Oberzolldirektion*) publishes these data since 1885. We use the *Monatsstatistik des auswärtigen Handels der Schweiz*, 1926–1938.[19]

The solution of the model described in Section 3.2 leads to a non–linear system of expectational first–order difference equations, which we log–linearize around its deterministic steady state,[20] before solving it using the method proposed by Klein (2000). The solution of the model provides the policy functions, which can be written in state space form as

$$\begin{aligned} \mathbf{x}_t &= \mathbf{Z}\boldsymbol{\alpha}_t; \\ \boldsymbol{\alpha}_t &= \mathbf{T}\boldsymbol{\alpha}_{t-1} + \mathbf{R}\boldsymbol{\nu}_t, \quad \boldsymbol{\nu}_t \sim N(\mathbf{0}, \mathbf{Q}), \end{aligned} \tag{3.29}$$

where $\mathbf{x}_t$ is a 3×1 vector of observables (output, inflation, and net exports), and $\boldsymbol{\alpha}_t$ is the 2×1 unobservable state vector driven by the two structural shocks in $\boldsymbol{\nu}_t$ with variance $\mathbf{Q}$. The model is of course a highly stylized representation of the Swiss economy in the 1930s. Therefore, we follow Ireland (2004) and incorporate a dynamic measurement error with a vector autoregressive (VAR) structure into the state vector to allow for off–model dynamics in the data:

$$\boldsymbol{\kappa}_t = \mathbf{A}\boldsymbol{\kappa}_{t-1} + \boldsymbol{\epsilon}_t, \quad \boldsymbol{\epsilon}_t \sim N(\mathbf{0}, \boldsymbol{\Sigma}). \tag{3.30}$$

[17] See Gordon (1939) and Koch (2000) for an overview. The index prior to 1926 is described in detail in Eidgenössisches Arbeitsamt (1923), the revised index in Bundesamt für Industrie, Gewerbe und Arbeit (1935).

[18] See Acklin (1939) and Balmer and Zurwerra (2000) for an overview.

[19] All data are available on request.

[20] See page 135 in Appendix A.2 for further detail regarding the technique of log–linearization applied.

The structure of the extended state space model is therefore

$$\mathbf{x}_t = \begin{pmatrix} \mathbf{Z} & \mathbf{I}_3 \end{pmatrix} \begin{pmatrix} \boldsymbol{\alpha}_t \\ \boldsymbol{\kappa}_t \end{pmatrix};$$
$$\begin{pmatrix} \boldsymbol{\alpha}_t \\ \boldsymbol{\kappa}_t \end{pmatrix} = \begin{pmatrix} \mathbf{T} & \mathbf{0} \\ \mathbf{0} & \mathbf{A} \end{pmatrix} \begin{pmatrix} \boldsymbol{\alpha}_{t-1} \\ \boldsymbol{\kappa}_{t-1} \end{pmatrix} + \begin{pmatrix} \mathbf{R} & \mathbf{0} \\ \mathbf{0} & \mathbf{I}_3 \end{pmatrix} \begin{pmatrix} \boldsymbol{\nu}_t \\ \boldsymbol{\epsilon}_t \end{pmatrix}. \tag{3.29'}$$

The setup allows to estimate the structural parameters of the model using Maximum Likelihood or Bayesian Markov Chain Monte Carlo (MCMC) methods. We choose the Bayesian approach, since in this framework, it is straightforward to impose parameter restrictions using the prior distribution. The restrictions are necessary because there is no guarantee that the estimation algorithm results in parameter estimates which make sense from an economic point of view. If this turns out to be too restrictive, the measurement error variance will dominate the variance of the structural model.

Lastly, we calibrate two structural parameters prior to the estimation exercise. In particular, we set the subjective discount factor β equal to the conventional value of 0.99 and the preference parameter γ equal to the import share of the Swiss economy during the period of investigation.

We impose uniform priors with reasonable ranges for the structural parameters to be as loose as possible (see Table 3.3).[21] To generate the parameter chain, we use the tailored randomized MCMC method proposed by Chib and Ramamurthy (2010). The procedure is a modification of the standard Metropolis–Hastings algorithm (e.g. Chib and Greenberg, 1995). In each simulation step, the parameters are randomly combined into blocks. A proposal draw is generated from a multivariate *t*–distribution with a scale matrix derived at the conditional maximum of the posterior. The proposal is accepted if the value of the posterior at the new parameters is higher than for the old parameters. If not, it is accepted with an

[21] For the VAR–component, we require that the maximum absolute eigenvalue of $\mathbf{A}$ is less than 0.6 to ensure that the persistence in the model comes from the structural shocks. In addition, the matrix $\boldsymbol{\Sigma}$ has to be positive semidefinite, and the maximum measurement error variance is not allowed to take values of more than 60 percent of the variance of the corresponding observable time series. This is similar to García-Cicco *et al.* (2010), who restrict the measurement error variance "to absorb no more than 6 percent of the variance of the corresponding observable time series" (p. 2519). Since the vectorized variance covariance matrix of the VAR part is given by $\mathrm{vec}(\boldsymbol{\Sigma}_\kappa) = (\mathbf{I}_{3^2} - \mathbf{A} \otimes \mathbf{A})\,\mathrm{vec}(\boldsymbol{\Sigma})$, our choice is not overly restrictive.

acceptance probability drawn from a uniform distribution $U(0,1)$, to ensure that we find a global maximum.

Since our estimation approach requires stationary data, we detrend our time series prior to estimation. Furthermore, in all our time series we observe a strong seasonal pattern. Therefore, we also deseasonalize the time series before the estimation. In particular, for output we use the cyclical component of a quadratically detrended and X–12[22] deseasonalized time series. For net exports we use a demeaned and X–12 seasonally adjusted time series, while for inflation we use monthly growth rates of year–to–year differences of the consumer price index. Data plots of the time series used for estimation can be found in Appendix B.2.

3.4 Results

This section presents the results and findings of our estimation exercise. Unless otherwise mentioned, we focus on the results using SBB freight data as a proxy for output. However, occasionally we also complement our findings with result sets using silk or watch production instead of freight data.

3.4.1 Parameter Distributions

With the algorithm described in the previous section, we draw 400,000 replications, discarding the first 150,000 as burn–in. Geweke's χ^2–test (4% taper) is used to assess convergence of the parameter chains (Geweke, 1992). Results of the posterior distribution of the structural parameters[23] are presented in Table 3.3 and show a presence of high persistence in foreign demand, terms of trade, and prices. This finding underlines the fact that price rigidities seem to be an important feature of the Swiss economy at this time.

3.4.2 Forecast Error Variance Decomposition

The decomposition of the forecast error variance, presented in Figure 3.7 of output and inflation shows that the structural model, even though being quite stylized,

[22] Census Bureau's X–12 ARIMA procedure

[23] Posterior distribution of measurement error components can be found in Appendix B.3.

Table 3.3: Posterior Distributions of Structural Parameters

Parameter	Prior Dist.	Median	90% Bands	Gewekes χ^2
β	calibrated	0.99	-	-
γ	calibrated	0.25	-	-
θ	$U \sim [5,7]$	6.425	[5.312,6.946]	0.358
η	$U \sim [1.5,3]$	2.660	[1.861,2.967]	0.875
σ	$U \sim [1.5,3]$	2.705	[2.026,2.969]	0.835
a	$U \sim [3,6]$	3.097	[3.009,3.373]	0.337
ω	$U \sim [0.4,1]$	0.995	[0.993,0.996]	0.878
$\rho_{y^\star}$	$U \sim [0,1]$	0.989	[0.983,0.993]	0.355
ρ_δ	$U \sim [0,1]$	0.999	[0.997,1.000]	0.189
$\sigma_{y^\star}$	$U \sim [0.01,0.03]$	0.020	[0.014,0.029]	0.615
σ_δ	$U \sim [0.01,0.03]$	0.010	[0.010,0.010]	0.371

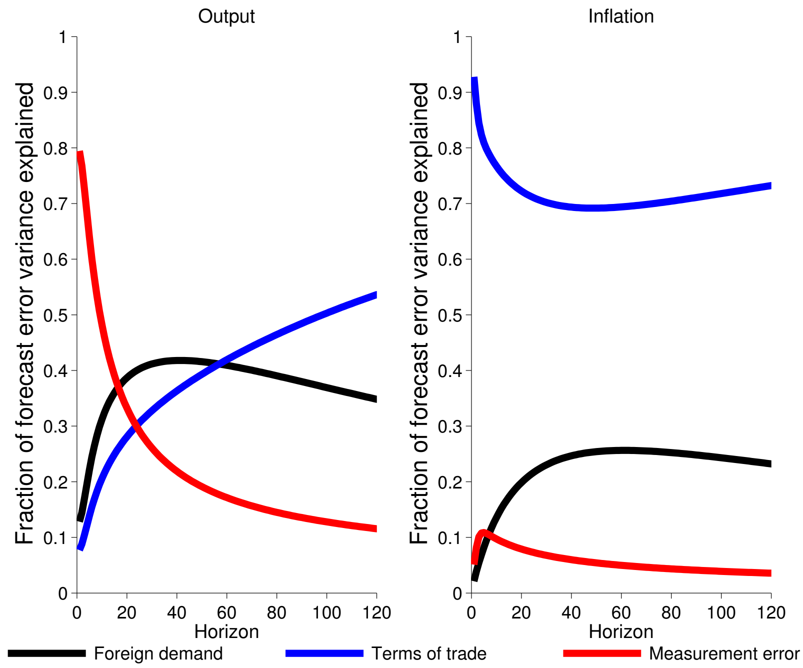
Notes: Results are based on 400,000 draws, where the first 150,000 are discarded as burn–in draws. SBB freight data is used for industrial production.

contributes a significant part to the dynamics in the data, especially in the long run. Thus, we conclude that the choice of the model, though being quite stylized, turned out to be appropriate and well–suited for explaining macroeconomic fluctuations of the Swiss economy during the Interwar Period.

Furthermore, the structural model is more important for inflation than for output – this demonstrates again that price rigidity is an important feature of the Swiss economy in this period. Inflation is mainly driven by movements in terms of trade both in the short and in the long run. Off–model dynamics are more important for output, which indicates that the model is not able to capture all the dynamics of this eventful period, especially in the short run. However, the structural part of the model becomes more and more important at longer horizons so that in the long run the measurement error only accounts for about 10 percent of the variation in output. Regarding the two structural shocks, foreign demand is slightly more important than terms of trade in the the short run, which in turn becomes more important in the long run.

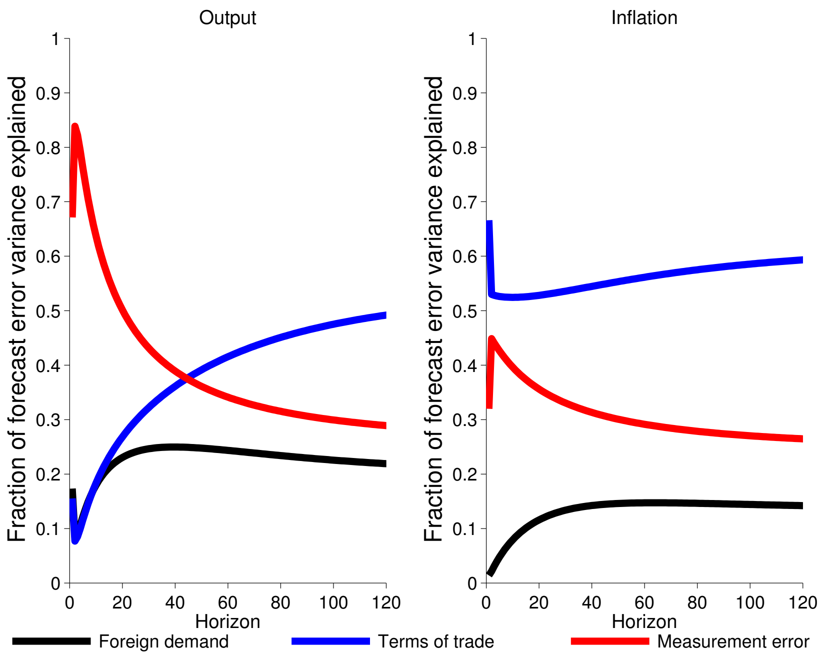
Figures 3.8 and 3.9 report the relative importance of the shocks in case we use silk or watch production as a proxy for output instead of SBB freight data. While the results reveal a worse model fit in general for these two specifications, we find qualitatively similar results for the forecast error variance decomposition. Hence, the importance of terms of trade turns out to be a robust finding.

Figure 3.7: Forecast Error Variance Decomposition (SBB)



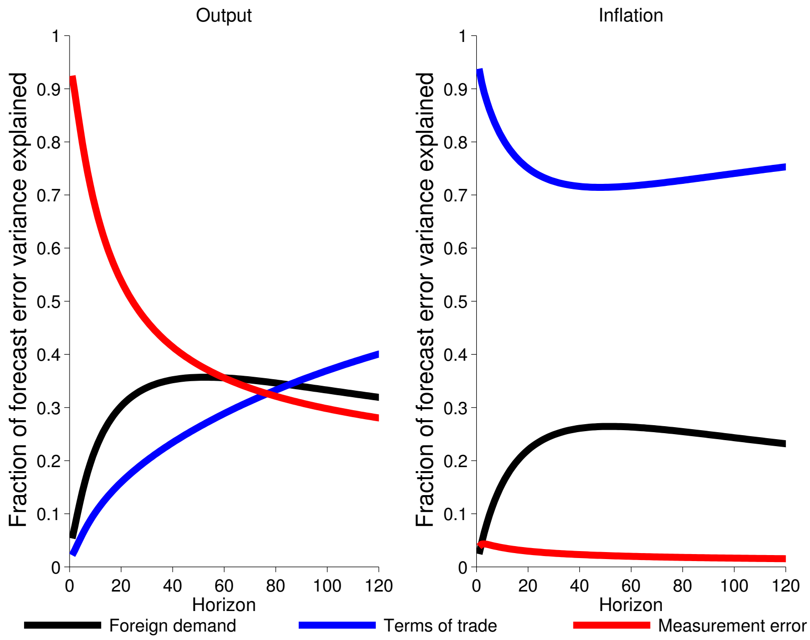
Notes: Results are based on median outcomes of the posterior distribution, SBB freight data is used for industrial production.

Figure 3.8: Forecast Error Variance Decomposition (Silk)



Notes: Results are based on median outcomes of the posterior distribution, silk production is used for industrial production.

Figure 3.9: Forecast Error Variance Decomposition (Watches)



Notes: Results are based on median outcomes of the posterior distribution, watch production is used for industrial production.

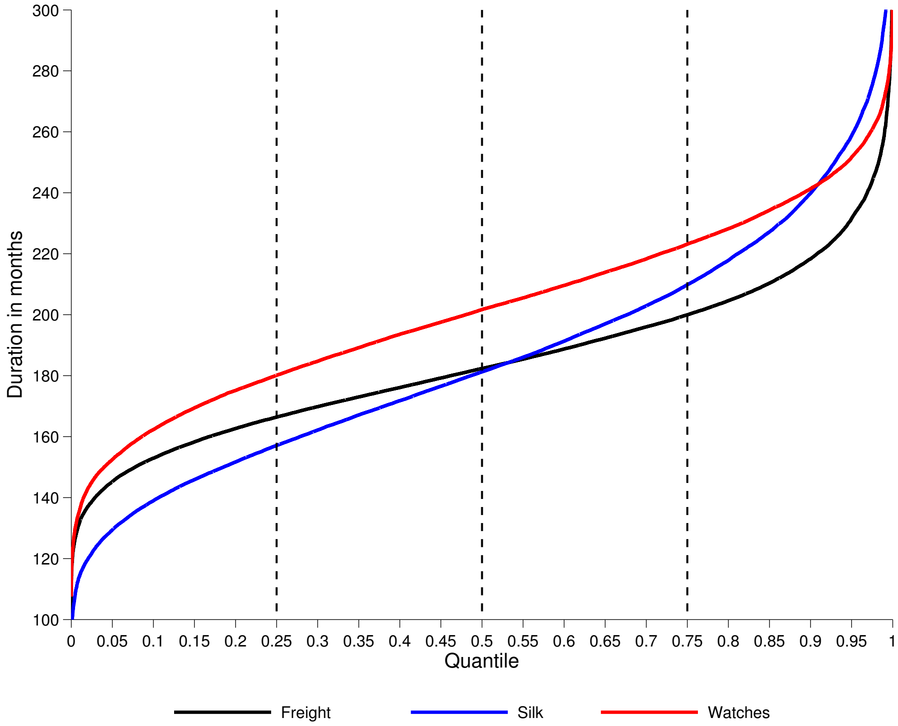
3.4.3 Price Rigidities

Another robust finding is the presence of severe price rigidities. Figure 3.10 depicts the distribution of the average duration of a price being effective implied by the estimated posterior distributions of ω. It reveals that independent of the choice of the output time series ω seemed to be rather high, which translates into a high degree of price stickiness. The remarkably high duration of prices being effective of the watches model is in line with an observed high degree of cartelization of the export sector as described in Section 3.2.

3.4.4 Estimated States

The fact that terms of trade and foreign demand are modeled as exogenous processes allows us to extract the model implied time series. The smoothed states displayed in Figure 3.11 are based on on 5,000 draws from the posterior distribution and using the Kalman filter to generate the time series. The foreign demand state shows the pattern of the business cycle for the main trading partners of

Figure 3.10: Average duration of prices $(\frac{1}{1-\omega})$

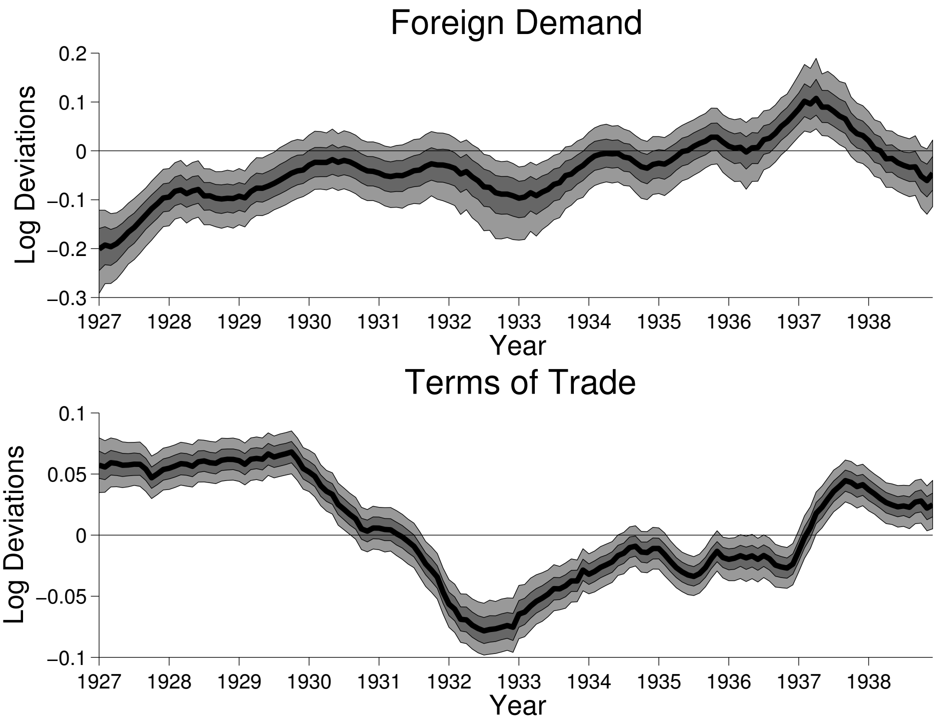


Notes: Average duration in months implies by the estimated posterior distributions.

Switzerland:[24] a downturn starting mid 1928, the lower turning point in 1932/33, and the recession 1936/37. This development should have helped Switzerland to escape earlier from the Great Depression. However, the terms of trade state shows that the Swiss franc stayed overvalued until autumn 1936. The sharp amelioration of the terms of trade time series almost perfectly coincides with the devaluation of the Swiss franc on September 26 in 1936. This finding is even more remarkable, since we did not include any data on exchange rates or terms of trade in the estimation exercise. A sharp decline after the outbreak of the Great Depression in 1929 can be observed, and the terms of trade did not reach equilibrium until the devaluation of the Swiss franc in September 1936. The forecast error variance decomposition of output reveals that terms of trade are more important than foreign demand. Consequently, the positive effect of increasing foreign demand after 1932/33 was overcompensated by the overvaluation of the Swiss franc, and the escape from the Great Depression did not start before September 1936.

[24]See Table 3.1 for the import and export shares of the main trading partners in this period.

Figure 3.11: Estimated Exogenous States



Notes: Results are based on 5,000 draws from the posterior distribution. Light–gray shaded area represents 95% probability bands, dark–gray shaded area represents 68% probability bands, black line represents median.

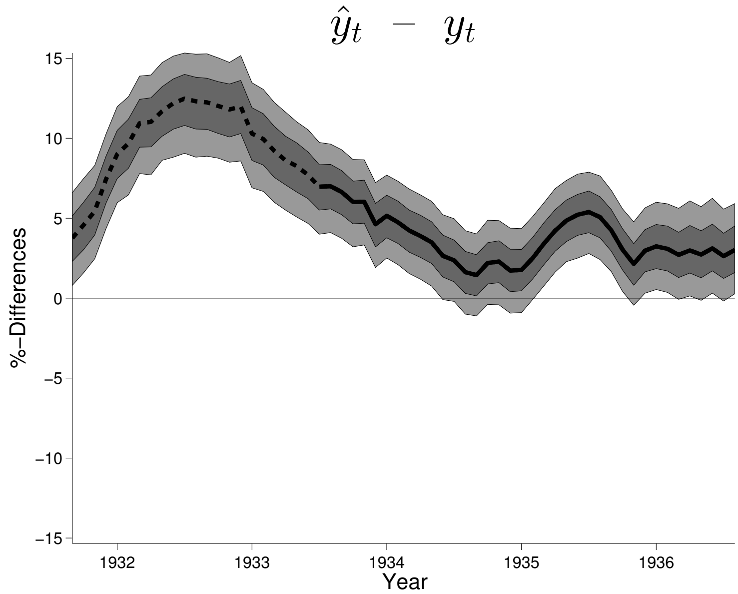
3.4.5 Counterfactual Experiments

Leaving Gold in 1931/33

What would have been the consequence of Switzerland leaving the Gold Standard together with Britain on September 21, 1931? What would have happened in case Switzerland did not participate in the Gold Block in July 1933 but devaluated their currency instead? To address the issue, we simulate the case of an early devaluation by setting the terms of trade state equal to one (i.e. the terms of trade are in equilibrium) and use 5,000 draws from the posterior parameter distribution and the Kalman filter to generate the counterfactual time series of interest. We calculate the differences between the predicted log deviations of output from the actual deviations, which is equal to percent differences in levels. As can be seen from Figure 3.12, this difference turns out to be always positive after 1932. This is in line with our previous interpretation: obviously, the overvaluation of the

Swiss franc against the sterling bloc and the US dollar caused the Swiss exporting sectors to profit less from the increasing demand after 1932/33 than small European countries with a devalued currency such as the Scandinavian countries. At least, there was some growth: in real terms, exports increased by 16 percent between 1932 and 1934. But in 1935, when sterling further weakened, the upward trend of exports decelerated.

Figure 3.12: Estimated Gain of Leaving Gold in September 1931 / July 1933



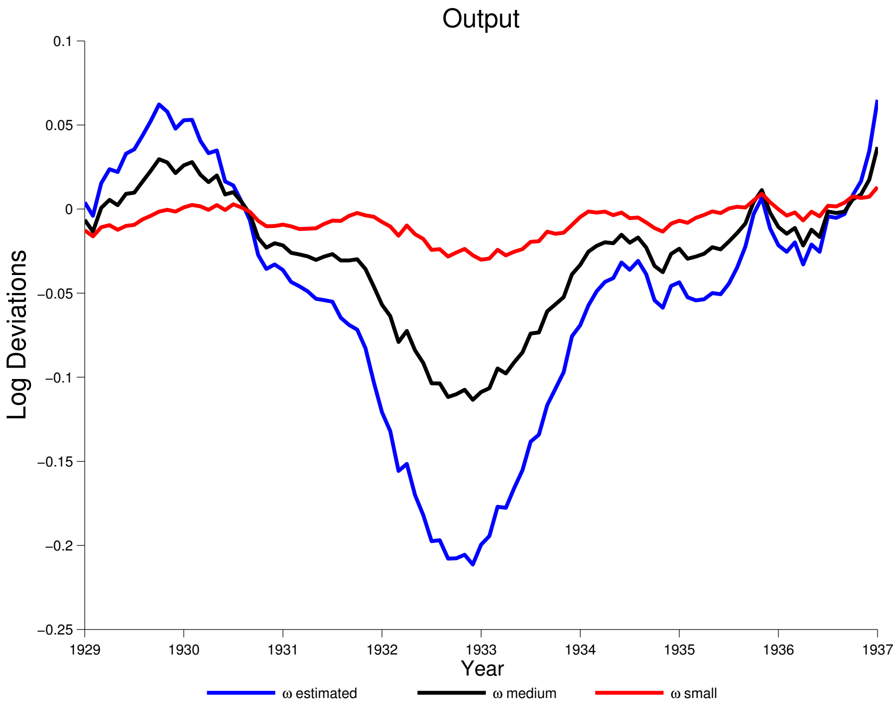
Notes: Results are based on 5,000 draws from the posterior distribution. Light–gray shaded area represents 95% probability bands, dark–gray shaded area represents 68% probability bands, black line represents median.

Alleviating Price Rigidities

What would have been the implications for the Swiss economy of a lower degree of price stickiness? Would a policy intervention decreasing the degree of cartelization have been beneficial? We draw 5,000 times from the posterior distribution and set ω equal to a lower counterfactual value. As a consequence, firms are in this experiment allowed to reset their price level more frequently. We analyze two different scenarios: (i) strong intervention (small ω): the average duration of prices being effective reduces from 182 to 50 months, and (ii) medium intervention (medium ω): the average duration of prices being effective reduces from 182 to

100 months. As a next step, we estimate the counterfactual level of output implied by the structural part of the model by generating counterfactual data. Figure 3.13 depicts the results and emphasizes the potential benefits of policies that reduce price rigidities. In particular, the extent to which the economy is exposed to cyclical fluctuations is significantly reduced with a lower ω. Hence, the severity of the Great Depression might have been amplified by the rise of corporatist policies.

Figure 3.13: Counterfactual Price Rigidities



Notes: Results are based on 5,000 draws from the posterior distribution, median outcomes are reported. Small ω implies an average duration of prices being effective of 50 months, while medium ω implies 100 months. ω estimated implies a median duration of prices of 182 months.

3.5 Conlusion

As Choudhri and Kochin (1980) show, countries staying on gold, such as Netherlands, Belgium, Italy or Poland, faced a much more severe depression than the Scandinavian countries or Spain, which never returned to gold. The Gold Bloc countries stayed depressed, while the countries leaving gold early recovered by 1935 (Eichengreen and Sachs, 1985; Campa, 1990; Bernanke and James, 1991; Eichengreen, 1992). The main determinants for the timing of abandoning the gold parity were deflationary pressure, the existence of banking crises, the gold cover ratio, and the extent of trade integration (Wolf, 2007, 2008).

The decision of Britain to abandon the gold standard on September 21, 1931 was seen as a catastrophe by contemporary Swiss policy makers.[25] Because of the fear of inflationary pressure caused by a floating exchange rate and the fact that the accumulated gold stock was big enough to avert speculative attacks, Switzerland managed to stay on gold until September 26, 1936.

What were the consequences of this policy for the Swiss economy? In a New Keynesian small open economy framework, we show that foreign demand deviations from equilibrium started to increase in the second half of 1931. This should have had a positive effect on Swiss output. However, at the same time, the terms of trade deteriorated. Since the contribution of the terms of trade shock to the forecast error variance of output was higher than the contribution of foreign demand, the second effect dominated, and it took the Swiss economy until autumn 1936 to start recovering from the Great Depression.

Finally, we detect a severe degree of price rigidity of the Swiss economy during the Interwar Period, which impeded an internal adjustment and therefore also contributed to a prolonged recession.

[25] An example is the evaluation of this step as "disastrous" in the 25th Anniversary Festschrift of the Swiss National Bank published in 1932: "*Am 21. September 1931 gab das durch große Goldabzüge bedrängte und dadurch in seinen Reserven bedrohte England die Goldwährung auf. Dieser Schritt war um so verhängnisvoller, als zahlreiche Staaten dem Beispiel Englands unmittelbar folgten*" (Schweizerische Nationalbank, 1932, p. 301/302).

Chapter 4

The Role of Labor Market Imperfections and Credit Constraints in the German Great Depression

4.1 Introduction

Brüning war an allem schuld.
L. A. Hahn (1963)

It is a long held public view that the economic policy of austerity under the chancellorship of Heinrich Brüning (March 1930 to June 1932), enforced by emergency decrees based on article 48 of the Weimar constitution, is to be blamed for deepening the depression and thus paving the path for the success of the National Socialist German Workers' Party (NSDAP). The hypothesis debated in the literature is that demand side policy would have been possible and that the success of NSDAP was a consequence of wrong economic policy (Ritschl, 2002, p. 32). The issues raised by Borchardt (1982) are taken as a point of departure: (1) When would have been the right time to intervene? There was no reason to act before spring/summer 1931, all crises before were different (e.g. the fast recoveries 1920/21 and 1925/26). Moreover, because of lags in the response to policy measures, it was too late in summer 1931 to stop the rapid increase in unemployment. (2) What would have been the right alternative policy? Alternatives discussed in the literature, such as the proposed credit expansion had no legal base. Because of the political situation, foreign credits were unlikely. A domestic monetary expansion was not possible because of the overriding aim to end the reparation payments of the Brüning government, the fear of inflation, and the missing political support. (3) A further question in the literature is the nature of the German crisis: In Borchardt's view, the crisis in Germany was not a cyclical phenomenon, but mainly structural. The German economy was *sick* and characterized by too high real wages and ongoing distributional struggles. This resulted in unfortunate initial conditions before the outbreak of the crisis, therefore an anticyclical demand side policy would not have been appropriate to solve the economic problems Germany had at this time.[1] All these issues remain unresolved, and this paper aims to contribute to the debate.

We study the situation in the framework of a Dynamic Stochastic General Equilibrium (DSGE) model, which allows to pin down the driving forces of the business cycle in a straightforward manner. In particular, we extend the model by Fisher and Hornstein (2002), by additionally modeling some of the key features of the German economy for the period under analysis. We make it an open economy, model labor market inefficiencies explicitly, and incorporate financial market frictions. We address the issue of the structural problems of the labor market measuring labor market frictions using a reduced form labor wedge (see Chari *et al.* 2002a, 2007 or Bridji 2013). Furthermore, we choose a heterogeneous agents framework to account for fact that the German economy was exposed to severe borrowing constraints (Ritschl, 2002) during this period. In addition, this extension yields the possibility to analyze different agents (capitalists and workers) separately.

We estimate a range of structural parameters of the model using monthly time series of output, consumption, and wages, all collected by the *Institut für Konjunkturforschung* in the 1920s and 1930s along the lines of Ireland (2004). This approach implements an autoregressive structure for the measurement error, thus enabling the highly restrictive, linearized solution of the DSGE model to compete with a

[1]On the Borchardt Controversy, see Borchardt (1982), Holtfrerich (1982, 1984, 1996), Ritschl (1990, 2002), and the overview in Kruedener (1990), especially Borchardt (1990) and Holtfrerich (1990). On the relative importance of high wages as opposed to high interest rates as a brake on investment, see Voth (1995).

more flexible time series model and to judge the goodness of fit. In principle, the estimation can be done using Maximum Likelihood, but given the high number of parameters to be estimated, numerical optimization is cumbersome, and it is more convenient to apply a Bayesian Markov Chain Monte Carlo (MCMC) technique.

Our results suggest that the German economy was characterized by severe structural problems. We find that the labor wedge (i.e. a wedge between the marginal rate of substitution of consumption for leisure and the marginal product of labor) plays a dominant role in explaining the downturn of the German business cycle. Furthermore, variations in total factor productivity (TFP), another supply side disturbance, also significantly contributed to the contraction of the economy. Regarding demand side policies, the model predicts a limited role for government interventions. Thus, expansionary fiscal policies would not have sufficed to prevent the German economy from falling into a depression. Consequently, our results support the point of view of Borchardt (1982) and highlight the importance of structural problems in the economy. Moreover, we find that (i) the economy was characterized by credit constraints as highlighted by Ritschl (2002) and (ii) capitalists suffered less during the Great Depression than the workers, since they were able to use financial markets to smooth consumption.

The remainder of the paper is structured as follows. The following section motivates and presents the model in detail. Section 4.3 presents the data used and the estimation approach. The results are discussed in Section 4.4, and Section 4.5 concludes.

4.2 The Model

We take the model used by Fisher and Hornstein (2002) as our point of departure. Additionally, for the purpose of our analysis, we extend the model on various dimensions. First, we make it a small open economy Real Business Cycle (RBC) model as introduced by Schmitt-Grohé and Uribe (2003) and applied by e.g. Aguiar and Gopinath (2007) in order to allow for open economy characteristics. In particular, we introduce a foreign interest rate, foreign debt, and thus also current account dynamics. This is motivated by the fact that the German economy was already quite open at that time, with an average ratio of 35 percent of exports and imports over output between 1925 and 1935.[2] In this regard, also Ritschl and Sarferaz (2014) highlight the importance of international financial movements as a transmission channel of the Great Depression.

Moreover, we augment the model with a financial friction by adapting a heterogeneous agents framework (see e.g. Judd 1985 and Angelopoulos *et al.* 2011). That is, we explicitly model capitalists and workers, where the latter type does not have access to domestic or international capital markets. The reason for this model innovation is twofold. First, the German economy was exposed to severe borrowing constraints during the Interwar Period as pointed out by Ritschl (2002, 2012, 2013). One major event here was the Young Plan in 1929, which ended the transfer protection of credits, thus leading to a decrease in foreign credit supply. Another factor imposing credit constraints on Germany was the outcome of the elections on September 14, 1930. With a very high voters turnout of 82%, the extreme parties to the right and left were successful, the NSDAP increasing the share of votes from 2.6% to 18.3%, and the KPD from 10.6% to 13.1%. In addition, the strained relationship with France, caused by a foreign policy which could be interpreted as aggressive, led to further complicating the situation.[3] On June 6, 1931, Brüning issued the second emergency deflation decree, together with an urgent demand to end reparations.[4] This speech was interpreted as yet another indication of German payment problems. In addition, there was the vulnerable German banking sector, as described in e.g. Born (1967, p. 14–30), everything culminating in the German banking crisis of 1931. Besides, this approach enables us analyze capitalists and workers individually, and thus contribute to discussions by Borchardt (1982) on distributional struggles.

In order to account for the role of the government, we follow Fisher and Hornstein (2002) by incorporating government spending as an exogenous state

[2] See Table B.7.4 in Ritschl (2002)

[3] Examples are the decision to build two new battle cruisers for the navy, the negotiations about an Austro–German customs union, and the exclusive bilateral trade agreements with Hungary and Romania.

[4] "*Die Einsetzung der letzten Kräfte und Reserven aller Bevölkerungskreise gibt der deutschen Regierung das Recht und macht es ihren eigenen Volk gegenüber zur Pflicht, vor der Welt auszusprechen: Die Grenzen dessen, was wir unserem Volk an Entbehrungen aufzuerlegen vermögen, ist erreicht!*" (in Winkler, 2005, p. 409)

variable. This allows us to analyze the importance of government spending during that time and thus to contribute to discussions whether or not expansionary government interventions could have prevented the German economy from falling into a depression. In light of the capitalists/worker financial friction, this shock becomes even more important. In our view, the interplay of government expenditure and credit restrictions faced by Germany are especially important, because all of the major plans discussed after 1931 to jump start the economy had to deal with the problem of financing the proposed job creating measures.[5]

Furthermore, we introduce a labor wedge[6] in the spirit of Chari *et al.* (2002a) and Chari *et al.* (2007), which enables us to assess inefficiencies of the German labor market present at that time. In fact, they also play an important role in the Borchardt Controversy (e.g. Borchardt, 1980, 1990; Holtfrerich, 1984; Ritschl, 1990).

Finally, a standard transitory TFP shock is introduced. It enables us to capture to what extent the economy was exposed to cyclical inefficiencies on the production side. Consequently, this model framework enables us to address some aspects of the Borchardt Controversy, while still being able to directly compare the results to the ones of Fisher and Hornstein (2002) or Chari *et al.* (2002a). The following Section 4.2.1 presents the model economy in detail.

4.2.1 The Economy

Producing Economy

The home economy is infinitesimal small and therefore does not influence any prices of the rest of the world. What is more, we abstract from any kind of

[5]The suggestion in the second report of the Brauns commission (*Kommission zum Studium der Arbeitslosenfrage*) in February 1931 was to finance the program by long run foreign credits (Röpke, 1931, p. 442). Hans Schäffer, on the other hand, in his *Gedanken zur Krisenbekämpfung* (September 2, 1931, in Schulz *et al.* 1980, Vol. 4/II, p. 933–939, No. 299) saw as only possibility rediscount policy of the *Reichsbank*, because obtaining foreign credits was unlikely, given the situation. This was also the opinion of Wilhelm Lautenbach (*Möglichkeiten einer Konjunkturbelebung durch Investition und Kreditausweitung*, September 16/17, 1931, in Borchardt and Schötz 1991, p. 307–325), who proposed to finance a public infrastructure investment program by credits from the *Reichsbank*. The so called WTB–plan (after the authors Wladimir Woytinski, Fritz Tarnow and Fritz Baade, *Wiederaufbau durch Arbeitsbeschaffung*, Schneider 1975, p. 231–236) of the ADGB (*Allgemeiner Deutscher Gewerkschaftsbund*) was also relying on expansionary monetary policy.

[6]See Shimer (2009) for a detailed discussion on findings on the labor wedge.

stochastic or deterministic trend in TFP growth. There is a representative firm that produces homogeneous final goods in a perfectly competitive environment. The production technology is described by the following neoclassical production function:

$$y_t = z_t k_t^{\alpha} (h_t)^{1-\alpha}, \tag{4.1}$$

where y_t denotes output, k_t capital available at period t and h_t labor input.[7] Moreover, the production technology is exposed to fluctuations in TFP, captured by z_t, which is assumed to follow a first–order autoregressive (AR(1)) stationary exogenous process in logs:

$$z_t = z^{1-\rho^z} z_{t-1}^{\rho_z} \exp(\epsilon_t^z) \qquad \text{with} \quad \epsilon_t^z \sim \mathcal{N}(0, \sigma_z^2). \tag{4.2}$$

Shocks to the level of TFP are captured by ϵ_t^z with variance σ_z^2. i_t represents the level of investment and the capital stock follows a law of motion of the following form:

$$k_{t+1} = (1-\delta)k_t + i_t - \frac{\phi}{2}\left(\frac{k_{t+1}}{k_t} - 1\right)^2 k_t, \tag{4.3}$$

where ϕ governs the quadratic capital adjustment costs and δ corresponds to the depreciation rate.

Factor Markets

Firms

Factor markets are competitive, resulting in a rental rate of capital equal to the marginal product of capital

$$r_t = \frac{\partial yt}{\partial k_t} = \alpha \frac{y_t}{k_t} \tag{4.4}$$

and a wage rate (from the producers point of view) equal to the marginal product of labor

[7]Note that in this class of models involuntary unemployment does not exist. Hence, we refrain from drawing strong conclusions concerning the determinants of the surge in the unemployment rate in Germany during the period under analysis.

$$w_t = \frac{\partial yt}{\partial h_t} = (1-\alpha)\frac{y_t}{h_t}. \tag{4.5}$$

This implies zero profits and therefore under market clearing

$$y_t = w_t h_t + r_t k_t, \tag{4.6}$$

and a capital (labor) share of α ($(1-\alpha)$) in the steady state.

Households: the Labor Wedge

Household's labor income is not necessarily equal to the full wage paid by the firms, because we allow for a wedge between the marginal rate of substitution of consumption for leisure and the marginal product of labor (i.e. the real wage) along the lines of Chari *et al.* (2002a, 2007). Thus, the relevant labor income for the agent's maximization problem is equal to $\tau_t w_t h_t$. τ_t captures the extent of labor market inefficiencies in a reduced form way and is allowed to vary over time following a stationary exogenous AR(1) process in logs:

$$\tau_t = \tau^{1-\rho^\tau}\tau_{t-1}^{\rho_\tau}\exp(\epsilon_t^\tau) \quad \epsilon_t^\tau \sim \mathcal{N}(0,\sigma_\tau^2). \tag{4.7}$$

As a result, the evolution of τ_t depends on the realizations of the shocks ϵ_t^τ with variance σ_τ^2. Furthermore, note that the wage difference resulting from the labor wedge ($(1\text{-}\tau_t)w_t h_t$) is redistributed in the form of a lump–sum transfer.

Government

The amount of non–productive government expenditure is described by the following law of motion, represented by another stationary exogenous AR(1) process in logs:

$$g_t = g^{1-\rho^g}g_{t-1}^{\rho_g}\exp(\epsilon_t^g) \qquad \text{with} \quad \epsilon_t^g \sim \mathcal{N}(0,\sigma_g^2). \tag{4.8}$$

It is financed by per capita lump–sum taxes t_t^g. The level of government expenditure depends on shocks ϵ_t^g with variance σ_g^2. Thus, we abstract from government debt and assume a balanced budget in every period. That is, in every period

$g_t = t_t^g$, where t_t^g denotes per capita lump sum transfers.The household however is free to choose how to finance t_t^g in every period. One option for example is the issuance of foreign debt d_t, which captures the level of foreign debt of the economy. Hence, in principle we allow for debt financed fiscal policy.

Households

Households form rational expectations and seek to maximize expected lifetime utility

$$\mathrm{E}_t \sum_{\tau=t}^{\infty} \beta^{\tau-t} u(c_\tau, 1-h_\tau), \tag{4.9}$$

where $\beta \in (0,1)$ denotes the subjective discount factor and $u(c_t, 1-h_t)$ the period utility function. It is assumed to be strictly increasing and strictly concave in both arguments consumption c_t and $(1-h_t)$ leisure. We assume that preferences are the same for both types of households (Angelopoulos *et al.*, 2011), and follow Fisher and Hornstein (2002) by using a log–linear utility function

$$u(c_t, 1-h_t) = \ln(c_t) + \eta \ln(1-h_t), \tag{4.10}$$

where η determines the leisure weight in the utility function. We set the mass of population equal to one, abstract from population growth in this model, and let λ determine the fraction of capitalists. Consequently, there are $\lambda \in [0,1]$ households of capitalists choosing their level of consumption, labor input, domestic capital, and foreign debt in order to maximize utility. Contrary to that, $(1-\lambda)$ households composed of workers can only choose their optimal level of consumption and labor input, because they do not have any access to financial markets. Finally, note that the two agents do not differ with respect to labor productivity.

Capitalists

The period t budget constraint of a capitalist is represented by:

$$\tau_t w_t h_t^k + r_t k_t^k + d_{t+1}^k = c_t^k + i_t^k + (1 + r_{t-1}^d) d_t^k + t_t^g + t_t^{t,k}, \tag{4.11}$$

where h_t^k, k_t^k, i_t^k, d_t^k, c_t^k correspond to a capitalist's labor supply, capital, investment, foreign debt, and consumption, respectively. All variables are expressed in per capita terms. Moreover, r_t^d denotes the interest rate on foreign debt and $t_t^{t,k}$ captures the aforementioned transfer resulting from the labor wedge. Thus, the left hand side of equation (4.11) captures the disposable resources of a capitalist at period t, composed of labor income $\tau_t w_t h_t^k$, capital income $r_t k_t^k$, and newly issued international debt d_{t+1}^k. These available resources are absorbed by consumption c_t^k, investment i_t^k, repayment of debt plus interest $(1 + r_{t-1}^d) d_t^k$, transfers due to the labor wedge $t_t^{t,k}$, and lump–sum taxes t_t^g to finance government expenditure g_t. Consequently, the optimization problem of a capitalist at time t can be stated as

$$\begin{aligned}
&\max_{\{c_\gamma^k, h_\gamma^k, k_{\gamma+1}^k, d_{\gamma+1}^k\}} \mathrm{E}_t \sum_{\gamma=t}^{\infty} \beta^{\gamma-t} (u(c_\gamma^k, 1 - h_\gamma^k)) \\
&\text{s.t.} \qquad \tau_\gamma w_\gamma h_\gamma^k + r_\gamma k_\gamma^k + d_{\gamma+1}^k \geq \\
&c_\gamma^k + \underbrace{k_{\gamma+1}^k - (1-\delta) k_\gamma^k + \frac{\phi}{2} \left(\frac{k_{\gamma+1}^k}{k_\gamma^k} - 1 \right)^2 k_\gamma^k}_{i_\gamma^k} + (1 + r_{\gamma-1}^d) d_\gamma^k + t_\gamma^{t,k} + t_\gamma^g
\end{aligned}$$

taking as given k_t^k, d_t^k, z_t, τ_t, and g_t as well as the transversality condition $\lim_{j\to\infty} \mathrm{E}_t \left[\prod_{s=0}^{j-2} \frac{d_{t+j}}{1+r_{t+s}^d} \right] = 0$. Utility maximization yields the following optimality conditions:

$$\frac{c_t^k}{1 - h_t^k} = \tau_t w_t \tag{4.12}$$

$$
\begin{aligned}
&\frac{1}{c_t^k}\left[1+\phi\left(\frac{k_{t+1}^k}{k_t^k}-1\right)\right] \\
&=\beta \mathrm{E}_t\left[\frac{1}{c_{t+1}^k}\left(r_{t+1}+(1-\delta)+\phi\left(\frac{k_{t+2}^k}{k_{t+1}^k}-1\right)\frac{k_{t+2}^k}{k_{t+1}^k}-\frac{\phi}{2}\left(\frac{k_{t+2}^k}{k_{t+1}^k}-1\right)^2\right]\right]
\end{aligned}
\tag{4.13}
$$

and

$$
\frac{1}{c_t^k}=\beta \mathrm{E}_t\left[\frac{1}{c_{t+1}^k}(1+r_t^d)\right]. \tag{4.14}
$$

Equation (4.12) represents the intratemporal labor–leisure trade–off condition including a labor wedge, while (4.13) and (4.14) describe the intertemporal Euler Equations with respect to capital and foreign debt holdings.

Workers

The period t budget constraint of a worker is represented by:

$$
\tau_t w_t h_t^w = c_t^w + t_t^g + t_t^{t,w} \tag{4.15}
$$

where h_t^w, c_t^k, $t_t^{t,w}$ correspond to the worker's labor supply, consumption, and transfers resulting from the labor wedge, respectively. All variables are expressed in per capita terms. The period t budget constraint takes into account that workers are excluded from financial markets and only have one income source. Consequently, their optimization problem at time t is static and is described below:

$$
\begin{aligned}
&\max_{\{c_\gamma^w, h_\gamma^w\}} \mathrm{E}_t \sum_{\gamma=t}^{\infty} \beta^{\gamma-t}(u(c_\gamma^k, 1-h_\gamma^k)) \\
&\text{s.t.} \quad \tau_\gamma w_\gamma h_\gamma^w \geq c_\gamma^w + t_\gamma^{t,w} + t_\gamma^g
\end{aligned}
$$

taking as given g_t, z_t, and τ_t. As optimality condition it only renders the intratemporal labor–leisure trade–off condition for workers (including the labor wedge)

$$
\frac{c_t^w}{1-h_t^w} = \tau_t w_t. \tag{4.16}
$$

Heterogeneous Agents: Aggregation

Since there are λ households of capitalists and $1-\lambda$ households of workers, the total economy's capital stock is equal to $k_t = \lambda k_t^k$, total economy's investment is equal to $i_t = \lambda i_t^k$, and the total level of foreign debt is equal to $d_t = \lambda d_t^k$. Furthermore, the total level of consumption is characterized by $c_t = \lambda c_t^k + (1-\lambda)c_t^w$, while the overall labor supply is equal to $h_t = \lambda h_t^k + (1-\lambda)h_t^w$.

Open Economy Characteristics

The open economy model is closed by a debt–elastic interest rate rule as proposed by Schmitt-Grohé and Uribe (2003):

$$r_t^d = r^d + \psi\left(\exp\left(d_{t+1} - d\right) - 1\right). \tag{4.17}$$

This approach has the advantage that besides being a convenient way of closing the open economy model, it also nests a potentially meaningful structural interpretation. That is, the parameter ψ governing the debt–elasticity of the economy can be interpreted as a reduced form financial frication in the spirit of García-Cicco *et al.* (2010). The extent to which the foreign interest rate depends on foreign debt dynamics might be driven by the degree of financial development. Additionally, since we allow for a foreign interest rate and foreign debt, we also include current account dynamics capturing changes in the net foreign asset position:

$$ca_t = -d_{t+1} + (1 + r_t^d)d_t. \tag{4.18}$$

Aggregation & Market Clearing

Finally, we can derive the standard aggregate resource constraint of the total economy by combining the budget constraints of workers and capitalists:[8]

[8]Note that we define total transfers due to labor market inefficiencies to be equal to $t_t^t \equiv \lambda t_t^{t,k} + (1-\lambda)t_t^{t,w}$

$$
\begin{aligned}
&\lambda\left(\tau_t w_t h_t^k + r_t k_t^k + d_{t+1}^k\right) + (1-\lambda)\left(\tau_t w_t h_t^w\right) = \\
&\lambda\left(c_t^k + k_{t+1}^k - (1-\delta)k_t^k - \frac{\phi}{2}\left(\frac{k_{t+1}^k}{k_t^k} - 1\right)^2 k_t^k + (1 + r_{t-1}^d)d_t^k + t_t^{t,k} + t_t^g\right) \\
&+ (1-\lambda)\left(c_t^w + t_t^{t,w} + t_t^g\right) \\
&\Leftrightarrow \tau_t w_t h_t + r_t k_t + d_{t+1} = c_t + i_t + (1 + r_{t-1}^d)d_t + g_t + \lambda t_t^{t,k} + (1-\lambda)t_t^{t,w} \\
&\Leftrightarrow y_t = w_t h_t + r_t k_t = c_t + i_t + g_t + ca_t + \underbrace{(\tau_t - 1)w_t h_t + t_t^t}_{=0} \\
&\Leftrightarrow w_t h_t + r_t k_t = y_t = c_t + i_t + g_t + ca_t
\end{aligned}
\tag{4.19}
$$

The left hand side of (4.19) captures income side of the economy, while the right hand side represents the expenditure side, both being equal to the produced amount y_t. A more detailed description of the model including all optimality conditions as well as the derivation of the steady state values can be found in Appendix C.1.

4.2.2 Model Solution

The above presented model represents a stationary system of non–linear first–order difference equations. We log–linearize the model around its deterministic steady state[9] and therefore apply a first–order approximation. As a next step we solve the linearized model applying the method proposed by Klein (2000). The solution can then be expressed in a state space representation of the form

$$
\begin{aligned}
\mathbf{y}_t &= \mathbf{Z}\boldsymbol{\alpha}_t \\
\boldsymbol{\alpha}_t &= \mathbf{T}\boldsymbol{\alpha}_{t-1} + \mathbf{R}\boldsymbol{\eta}_t, \quad \boldsymbol{\eta}_t \sim N(\mathbf{0}, \mathbf{Q}),
\end{aligned}
\tag{4.20}
$$

where $\mathbf{y}_t$ is an $(n \times 1)$ vector of control variables and $\boldsymbol{\alpha}_t$ represents the $(m \times 1)$ unobservable state vector, which is driven by the exogenous processes $\boldsymbol{\eta}_t$ of dimension $(x \times 1)$. The matrix $\mathbf{R}$ $(m \times x)$ links the state variables to the exogenous

[9]See page 135 in Appendix A.2 for further detail regarding the technique of log–linearization applied.

processes. In our case we have two endogenous state variables k_t and d_t, and three exogenous state variables z_t, g_t, and τ_t, resulting in $m = 5$ and $x = 3$. $\mathbf{Q}$ represents the variance covariance matrix of the state variables, where only the last three elements on the main diagonal are non–zero and equal to σ_z^2, σ_g^2, and σ_τ^2. $\mathbf{Z}$ $(n \times m)$ and $\mathbf{T}$ $(m \times m)$represent policy functions of all the variables in the system. Finally, we use this state space representation to estimate the model, which is described in the next section.

4.3 Calibration, Data, and Estimation

4.3.1 Calibration

A set of structural parameters and steady state conditions is calibrated. We closely follow the literature, particularly Fisher and Hornstein (2002), in order to assure comparability to existing results. Table 4.1 reports the calibrated values. Having monthly data available (see next section), we also use a monthly frequency for the analysis, i.e. a time unit t in our theoretical economy is equal to one month.

Table 4.1: Calibrated Values

Parameter	Description	Value
β	subjective discount factor	0.997
r	steady state real interest rate	0.004
δ	steady state depreciation rate	0.001
α	capital share of the economy	0.25
ψ	debt–elasticity of foreign interest rate	1
ϕ	capital adjustment costs	0
h	steady state labor supply	0.30
$\frac{g}{y}$	steady state public expenditure quota	0.15
$\frac{d}{y}$	steady state debt–to–GDP ratio	0.80
z	steady state level of transitory TFP	1
τ	steady state level of labor wedge	1

We use calibrated values of Fisher and Hornstein (2002) for β and δ and adjust them to be consistent with a monthly frequency to derive steady state values for β, r, and δ. With respect to the steady state capital share of the economy we also follow Fisher and Hornstein (2002) and set it equal to 0.25. On an annual basis, this calibration would imply a capital–to–output ratio of about 5 and an interest rate of about 5 percent. Also, regarding steady state labor supply h we follow Fisher and Hornstein (2002) and set it equal to 0.3. We fix the debt–elasticity parameter ψ at value 1, which implies a certain amount of financial frictions on the international debt market. While e.g. Aguiar and Gopinath (2007) use the value 0.001, which basically excludes any feedback effects from the interest rate to variations in the level of debt, García-Cicco *et al.* (2010) point out that this parameter needs to be carefully calibrated or estimated. A too low value could result in imprecise or misleading model predictions, particularly for the current account. Hence, given the fact that Germany was exposed to severe external credit constraints in the Interwar Period (Ritschl, 2002, 2012, 2013), we choose a calibration[10] significantly different from zero. We calibrate the steady state ratio of government spending to be equal to 0.15 using data provided by Ritschl (2002) ranging from 1925–1935. With respect to the steady state foreign debt–to–GDP we use data from Ritschl and Sarferaz (2014). The average ratio from 1928–1932 is equal to 80 percent. Moreover, we do not assume any inefficiencies on the production side or on the labor market in the steady state and therefore set z and τ equal to 1. Finally, we abstract from capital adjustment costs.[11] All remaining structural parameters, including the share of capitalists, are estimated.

4.3.2 Data

For the estimation exercise, we use monthly data collected by the *Institut für Konjunkturforschung* on output (production index),[12] consumption (approximated

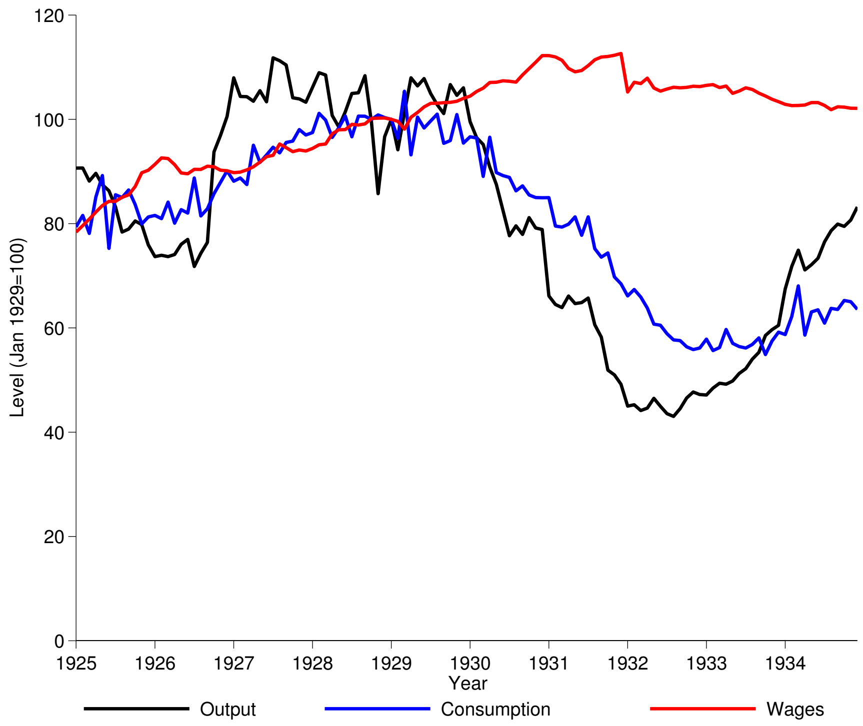
[10]We are aware of the fact that an estimation of this parameter would be desirable. In our case however, this is rather cumbersome, since the policy functions of our control variables we use for the estimation are independent of the value of ψ. As a result, we cannot identify ψ. One would require high quality monthly time series of real interest rates (preferably domestic and international) and foreign debt to estimate ψ. Still, we conducted several robustness checks with other values of ψ and concluded that the choice of ψ did not significantly alter our results.

[11]We also estimated the model with positive capital adjustment costs and could not detect any major differences.

[12]Institut für Konjunkturforschung (1935, Section III B, p. 52 f.), *Produktionsgüter gesamt* (1928=100). For a discussion and critique of available production indices at this time, see Ritschl (2004).

by retail sales),[13] and wages (hourly wages of workers).[14] Furthermore, in order to have data being consistent with the model, we require real and per capita time series. Hence, we divide the series of output and consumption by population[15] and deflate them using the consumer price index.[16] As a next step, all three time series are seasonally adjusted using using the Census Bureau's X–12 ARIMA procedure.

Figure 4.1: Data



Notes: Normalized indices (Jan 1929=100) of seasonally adjusted real per capita output, real per capita consumption, and real wages.

Figure 4.1 depicts the resulting time series and immediately points out that there seems to be a divergence between wages and the other variables. While both output and consumption experienced a severe deterioration during the Great Depression, real wages even increased. This highlights the phenomenon of over-

[13] Institut für Konjunkturforschung (1933, Section VI A,p. 64), Institut für Konjunkturforschung (1935, Section VI A, p. 78), *Umsatzbewegung im Einzelhandel, Einzelhandel insgesamt* (1928=100).

[14] Institut für Konjunkturforschung (1933, Section VIII D, p. 82), *Stundenlöhne (Durchschnitt)*, (1928=100).

[15] We use annual population data of the International Financial Statistics (IFS) database and construct monthly time series by linear interpolation.

[16] Institut für Konjunkturforschung (1933, Section IX C, p. 116 f.), *Reichsindexziffern der Lebens–haltungskosten, Lebenshaltung insgesamt* (1913/14=100).

valued and rigid wages in the German economy mentioned by Borchardt (1982).

Moreover, our estimation procedure requires the use of stationary data. Hence, we need to choose an appropriate filter of in order make the time series stationary. Thus, we decide to use deviations of a quadratic trend for the estimation.

4.3.3 Estimation

We adopt a Bayesian viewpoint for the estimation exercise. This approach allows us to incorporate prior beliefs about the structural parameters of interest in a convenient way. Furthermore, it yields computational advantages vis–à–vis a classical estimation approach.

What concerns the choice of the parameters to be estimated, we focus on the persistence parameters and volatility of the exogenous shocks. Consequently, estimation results will determine which shocks were the main determinants of the German business cycle during the Great Depression. Additionally, we also estimate the parameter λ (i.e. the share of capitalists in the economy), the reason being twofold: First, a proper calibration would be rather cumbersome. One option would be to use household survey data on savings (as Angelopoulos *et al.* 2011) in order to pin down down λ. Such data however is rather difficult to obtain for the Interwar Period in Germany. Another approach would be to approximate $(1-\lambda)$ using data on the share of workers and public servants. Still, one would need to assume that those groups were excluded from financial markets. As a result, we decided to estimate the parameter λ directly. All other structural parameters are calibrated and reported in Table 4.1.

Our estimation strategy builds on Sargent (1989) and Ireland (2004) by including (vector–)autoregressive "measurement error" component to capture the dynamics in the data that cannot be replicated by the structural model itself. Especially in turbulent times such as the Great Depression, a rather stylized model certainly is not capable to account for all the dynamics in real macroeconomic time series. Thus, the degree of importance of the measurement error in explaining variations in the control variables may directly be interpreted as a measure of model fit. Accordingly, for estimation purposes, our linearized model yields the following state space representation:

$$\begin{aligned}
\mathbf{y}_t =& \mathbf{Z}\boldsymbol{\alpha}_t + \boldsymbol{\kappa}_t \\
\boldsymbol{\kappa}_t =& \mathbf{A}\boldsymbol{\kappa}_{t-1} + \boldsymbol{\epsilon}_t, \qquad \boldsymbol{\epsilon}_t \sim \mathcal{N}(\mathbf{0}, \boldsymbol{\Sigma}) \\
\boldsymbol{\alpha}_t =& \mathbf{T}\boldsymbol{\alpha}_{t-1} + \mathbf{R}\boldsymbol{\eta}_t, \qquad \boldsymbol{\eta}_t \sim \mathcal{N}(\mathbf{0}, \mathbf{Q})
\end{aligned} \tag{4.20$'$}$$

where $\mathbf{y}_t$ is an $(n_e \times 1)$ vector of control variables used for the estimation. The state space equation describing $\boldsymbol{\alpha}_t$ remains unchanged. Concerning the off–model dynamics, $\boldsymbol{\kappa}_t$ is a $(n_e \times 1)$ vector of measurement errors with a $(n_e \times 1)$ vector of shocks $\boldsymbol{\epsilon}_t$ with a variance–covariance matrix $\boldsymbol{\Sigma}$. We assume that off–model dynamics follow autoregressive processes, such that all off–diagonal entries of the $(n_e \times n_e)$ coefficient matrix $\mathbf{A}$ are restricted to be equal to zero. Since we are using output, consumption, and wages for the estimation, n_e is equal to 3.

We apply a MCMC simulation using a Metropolis–Hastings algorithm within the Gibbs sampler to derive posterior distributions of the parameters of interest. In particular, we apply a Gibbs sampler to simulate the posterior distributions of the parameters characterizing our exogenous processes, while we we add a Metropolis–Hastings step in order to approximate the posterior distribution of the capitalist share λ. Further details on the estimation algorithm can be found in Appendix C.4.

The prior distributions are reported in Table 4.2 in Section 4.4.1. λ is naturally bounded between zero and one. As a result, we choose a uniform distribution between 0.001[17] and 1. Regarding the autoregressive parameters of the structural shocks we chose a normal distribution with mean 0.95. Since we are analyzing a model with a monthly frequency, we expect rather persistent shocks. On the contrary, we do not have any prior beliefs concerning the persistence parameters of the measurement errors. Thus, we assume a normal distribution with zero mean. Moreover, we harmonize the variance of the normal distributions of the prior distributions of all autoregressive parameters to be equal to 0.01, thus allowing for a relatively lose prior. Finally, we also harmonize the prior distributions for all variance parameters to follow an inverse Gamma distribution implying a mean of

[17] We need some positive mass of capitalists to hold the economy's capital.

0.01 with variance 0.002. Note that this does not yield any further restrictions on the measurement error components as opposed to e.g. García-Cicco *et al.* (2010).

4.4 Results

4.4.1 Parameter Distributions

In our estimation exercise, we draw 70,000 replications, discarding the first 30,000 draws as burn–in. To break autocorrelation, we only regard every tenth draw for further analysis. Geweke's χ^2–test is used to assess convergence of the parameter chains (Geweke, 1992). Results of the posterior distribution of the parameters are presented in Table 4.2.

Table 4.2: Prior & Posterior Distributions

Parameter	Prior Dist.	90% Bands	Post. Median	90% Bands	χ^2
λ	$\mathcal{U}(0.001, 1)$	–	0.40	[0.28,0.59]	0.53
ρ_z	$\mathcal{N}(0.95, 0.01)$	[0.79,1.11]	0.96	[0.93,0.99]	0.13
ρ_g	$\mathcal{N}(0.95, 0.01)$	[0.79,1.12]	0.93	[0.86,0.98]	0.44
ρ_τ	$\mathcal{N}(0.95, 0.01)$	[0.79,1.12]	0.98	[0.96,1.00]	0.64
ρ_{ϵ_y}	$\mathcal{N}(0, 0.01)$	[−0.16,0.16]	0.11	[−0.01,0.24]	0.48
ρ_{ϵ_c}	$\mathcal{N}(0, 0.01)$	[−0.16,0.16]	−0.06	[−0.17,0.06]	0.52
ρ_{ϵ_w}	$\mathcal{N}(0, 0.01)$	[−0.16,0.16]	0.14	[0.02,0.27]	0.27
$\sigma_z^2 \times 100$	$\mathcal{IG}(2.05, 0.015)$	[0.31,4.01]	0.03	[0.03,0.04]	0.17
$\sigma_g^2 \times 100$	$\mathcal{IG}(2.05, 0.015)$	[0.31,4.01]	2.22	[1.20,3.93]	0.78
$\sigma_\tau^2 \times 100$	$\mathcal{IG}(2.05, 0.015)$	[0.31,4.01]	0.15	[0.12,0.18]	0.62
$\sigma_{\epsilon_y}^2 \times 100$	$\mathcal{IG}(2.05, 0.015)$	[0.31,4.01]	0.07	[0.05,0.09]	0.53
$\sigma_{\epsilon_c}^2 \times 100$	$\mathcal{IG}(2.05, 0.015)$	[0.31,4.01]	0.09	[0.07,0.11]	0.20
$\sigma_{\epsilon_w}^2 \times 100$	$\mathcal{IG}(2.05, 0.015)$	[0.31,4.01]	0.02	[0.02,0.03]	0.92

Notes: Results are based on 70,000 draws from the posterior distribution, of which the first 30,000 draws were burned. To avoid autocorrelation issues, we only keep every 10^{th} draw. The χ^2 figure denotes the *p*–value of Geweke's χ^2–test for convergence (4% taper).

We observe a mean of the parameter λ of 0.4. Data provided by Petzina *et al.* (1978, p. 55) is in line with this estimate. Both in the years 1925 and 1933, the share of workers and public servants was equal to about 67 percent. On the other hand, the share of self employed and related family members working amounted to about 33 percent. Hence, assuming that a subset of workers also had access to financial markets, a share of 40 percent of capitalists seems to match the historical data.

All structural autoregressive parameters turn out to be quite persistent. Concerning structural shocks, we observe the highest variance for government expenditure, and the lowest for TFP. To what extent this translates into relative importance of explaining the dynamics in the data, we conduct a forecast error variance decomposition, which is presented in the following section.

4.4.2 Forecast Error Variance Decomposition

Model Fit

Before discussing the results, we are assessing the capability of the model fitting the data we used for the estimation. For this purpose, we compute the fraction of variance explained by the structural part of the model and compare it to the off–model part. The results are presented in Table 4.3.

Table 4.3: Forecast Error Variance Decomposition: Model Fit

Horizon	0		12		120	
Variable \ Shock	Structural	ME	Structural	ME	Structural	ME
Output	72.8	27.2	96.2	3.8	98.3	1.7
Consumption	24.5	75.5	76.9	23.1	93.6	6.4
Wages	60.7	39.3	93.2	6.8	96.3	3.7

Notes: Forecast error variance decompositions (in percent) are based on median outcomes of the posterior distribution. ME denotes measurement error, and it captures the extent to which dynamics are driven by off–model dynamics.

First, we observe that the model is able to account for the large bulk of the dynamics in the data, especially in the long run (i.e. forecast horizon of 120 months). Second, we find that the model fit improves at larger forecast horizons. Third, the model performs best in explaining output variations, while for the case of consumption the fit is worse, especially on impact (i.e. forecast horizon of 0 months). Hence, we conclude that the choice of the model, even though being quite stylized, turned out to be appropriate in explaining the dynamics of the German business cycle during the period under analysis.

Aggregate Economy

Table 4.4 summarizes the relative contributions of the structural shocks disregarding the effects of the measurement error. We find that both variations in TFP and the labor wedge play an important role in explaining the German business cycle, while government expenditure shocks only account for little dynamics. Shocks to the labor wedge are particularly important in the long run, where they explain 50 percent or more of the variation in most variables. This result highlights the presence of severe labor market frictions in the German economy. Moreover, variations in TFP also account for a significant amount of the variation in most variables. On the other hand, the influence of government expenditure shocks varies from 3 to 7 percent, only for consumption it is slightly more pronounced. Thus, one can conclude that the business cycle was not driven by government expenditure shocks. Consequently, the results suggest that there was little scope for countercyclical demand side policies.

Table 4.4: Forecast Error Variance Decomposition: Aggregate Economy

Horizon	0			12			120		
Variable \ Shock	z_t	g_t	τ_t	z_t	g_t	τ_t	z_t	g_t	τ_t
Output	41.8	4.6	53.6	36.9	2.9	60.2	25.4	1.5	73.1
Consumption	33.3	23.3	43.5	32.0	14.9	53.1	20.0	4.6	75.4
Wage	65.9	2.7	31.4	65.8	2.1	32.1	68.2	1.8	30.0
Capital	40.6	7.6	51.8	37.1	5.4	57.5	19.7	1.3	79.0
Labor Input	7.6	7.3	85.0	5.9	4.7	89.4	3.7	2.6	93.7
Foreign Debt	40.8	4.4	54.8	35.5	3.8	60.7	30.8	3.8	65.4
Investment	40.6	7.6	51.8	36.3	5.1	58.6	28.8	3.3	68.0
Return to Capital	41.8	4.6	53.6	36.6	3.9	59.5	31.6	3.9	64.5
Foreign Int. Rate	40.8	4.4	54.8	35.5	3.8	60.7	30.8	3.8	65.4
Current Account	40.8	4.4	54.8	37.4	4.0	58.6	32.3	3.9	63.8

Notes: Forecast error variance decompositions (in percent) are based on median outcomes of the posterior distribution. Only fluctuations caused by structural shocks are considered.

Heterogeneous Agents

Table 4.5 sheds light on the relative importance of the structural shocks regarding consumption and labor supply of capitalists and workers.

We observe that government spending is far more important for the worker than for the capitalist, both for labor supply and consumption dynamics. One

Table 4.5: Forecast Error Variance Decomposition: Heterogeneous Agents

Horizon	0			12			120		
Variable \ Shock	z_t	g_t	τ_t	z_t	g_t	τ_t	z_t	g_t	τ_t
Cons. Capitalist	12.8	7.1	80.1	15.8	4.5	79.8	14.9	1.2	83.9
Cons. Worker	36.9	26.4	36.6	36.1	17.9	46.0	24.4	7.5	68.1
Labor Capitalist	23.3	0.3	76.4	18.9	0.1	81.0	12.9	0.1	87.0
Labor Worker	0.4	40.6	59.0	0.4	28.3	71.3	0.4	15.0	84.7

Notes: Forecast error variance decompositions (in percent) are based on median outcomes of the posterior distribution. Only fluctuations caused by structural shocks are considered.

explanation could be the worker's lack of access to financial markets. After a positive government expenditure shock a worker must immediately adjust the level of consumption and labor supply, while a capitalist can also issue new debt or reduce investment in order to finance the increased need of g_t. Furthermore, also for these variables the labor wedge is the most important structural state variable, while the evolution of TFP also accounts for some variations.

4.4.3 Impulse Response Analysis

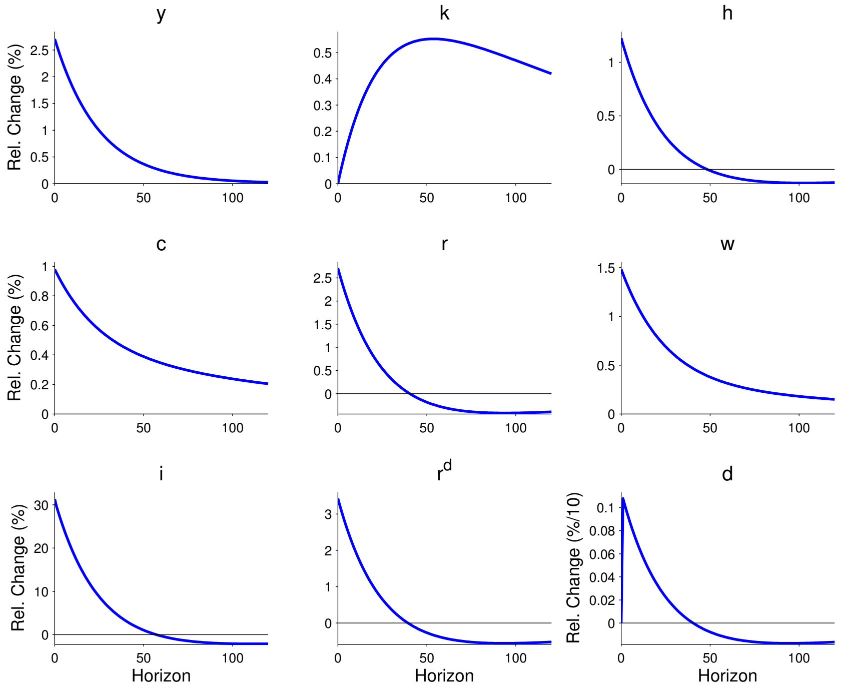
Next, we present impulse response functions to structural shocks of a size of one standard deviation. All impulse response functions are evaluated at the median of the posterior distribution.

Total Factor Productivity Shock

Aggregate Economy

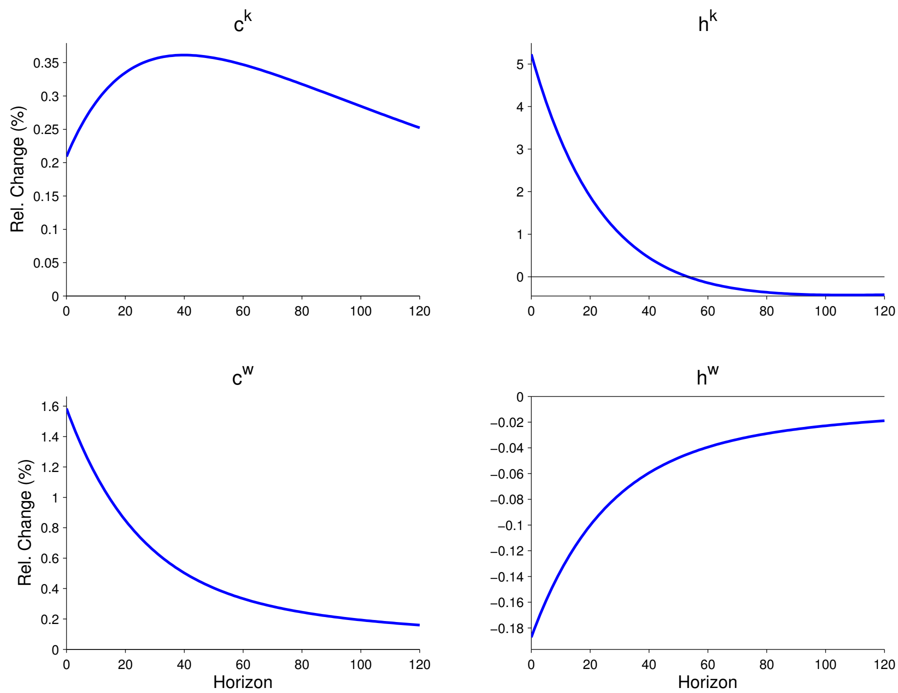
A positive shock to TFP leads *ceteris paribus* to an increase in output, the return to capital, and the wage rate. Households increase investment and labor supply, which further increases the level of output. This leads to an increased factor income, resulting in an increase in consumption. Lastly, households also increase their level of foreign debt to finance further investment, which leads to an increase in the foreign interest rate. It it worth noting that impulse responses exhibit rather persistent effects. For example, the capital stock is still above its steady state level ten years after the shock.

Figure 4.2: Impulse Responses (z_t–Shock): Aggregate Economy



Notes: Impulse responses to a one standard deviation shock evaluated at the median of the posterior distribution.

Figure 4.3: Impulse Responses (z_t–Shock): Heterogeneous Agents



Notes: Impulse responses to a one standard deviation shock evaluated at the median of the posterior distribution.

Heterogeneous Agents

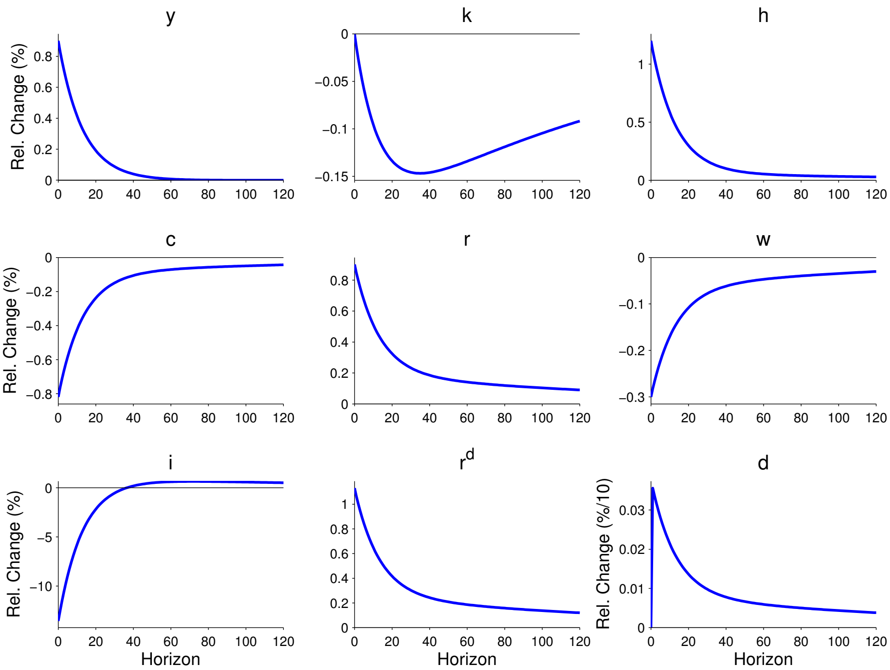
The responses for the the two types of agents are different. While the responses of the capitalists are similar to the ones of the aggregate economy (i.e. $c^k \uparrow$ and $h^k \uparrow$), the implications for a worker's household are different. In particular, it consumes significantly more, while slightly reducing the level of labor supply.

Government Expenditure Shock

Aggregate Economy

A positive shock to g_t leads to a decrease in private consumption, investment and thus subsequently the capital stock. In order to countervail this negative disposable income shock, labor supply increases and leads eventually to an increase in output and a decrease in the wage rate. The level of foreign debt increases, which implies some degree of external funding of the increased need of government spending.

Figure 4.4: Impulse Responses (g_t–Shock): Aggregate Economy

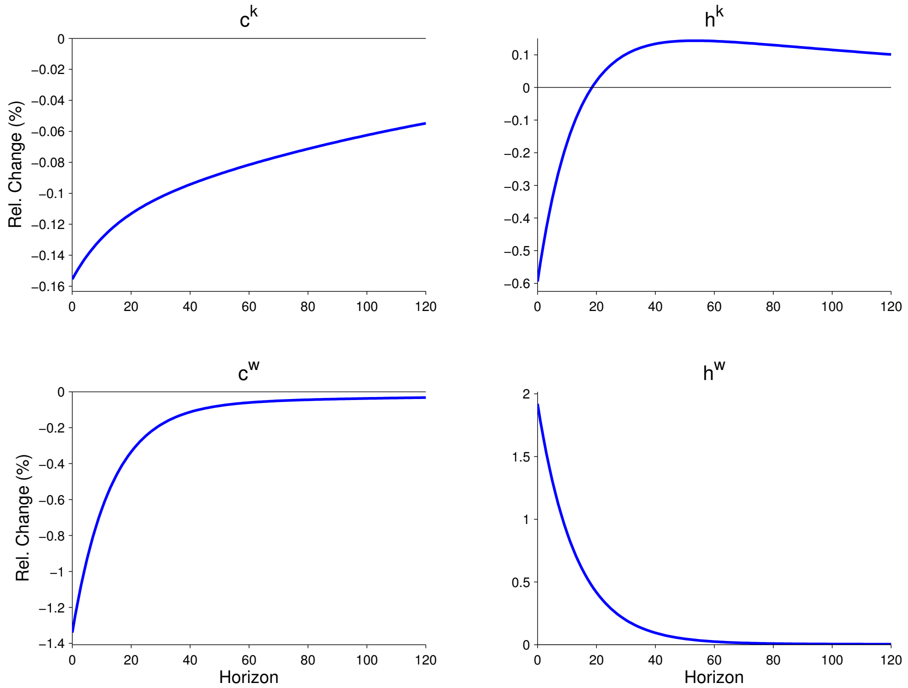


Notes: Impulse responses to a one standard deviation shock evaluated at the median of the posterior distribution.

Heterogeneous Agents

Again we observe opposing effects for both types of households. While workers increase their labor supply in order to finance the government spending shock and to cushion the decrease in consumption, capitalists even work less and use foreign debt to finance g_t. It is important to point out that the responses of workers are far more pronounced, which supports the findings on the importance of the government spending shock for workers in the previous section.

Figure 4.5: Impulse Responses (g_t–Shock): Heterogeneous Agents



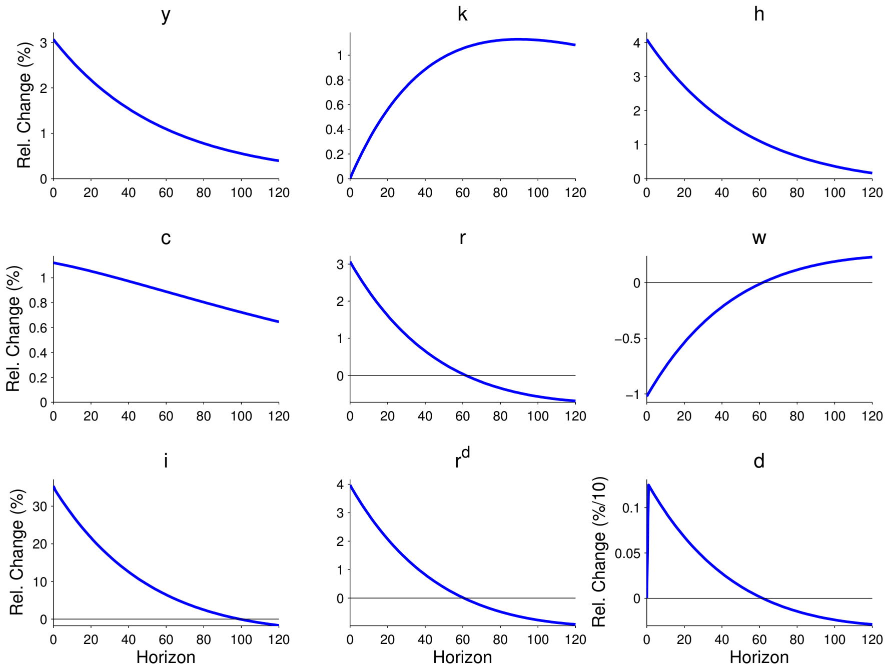
Notes: Impulse responses to a one standard deviation shock evaluated at the median of the posterior distribution.

Labor Wedge Shock

Aggregate Economy

Finally, we analyze a positive shock to the labor wedge τ_t. Note that the dynamics are similar to the ones of a negative labor tax shock. Clearly, an increase in the labor wedge leads to a strong increase in labor supply, which significantly reduces the real wage. The boost in labor supply increases output and thus the marginal product of capital, resulting in increased investment activities. Consequently, a labor wedge shock yields expansionary effects on output and further leads to a positive reaction of aggregate private consumption.

Figure 4.6: Impulse Responses (τ_t–Shock): Aggregate Economy



Notes: Impulse responses to a one standard deviation shock evaluated at the median of the posterior distribution.

Heterogeneous Agents

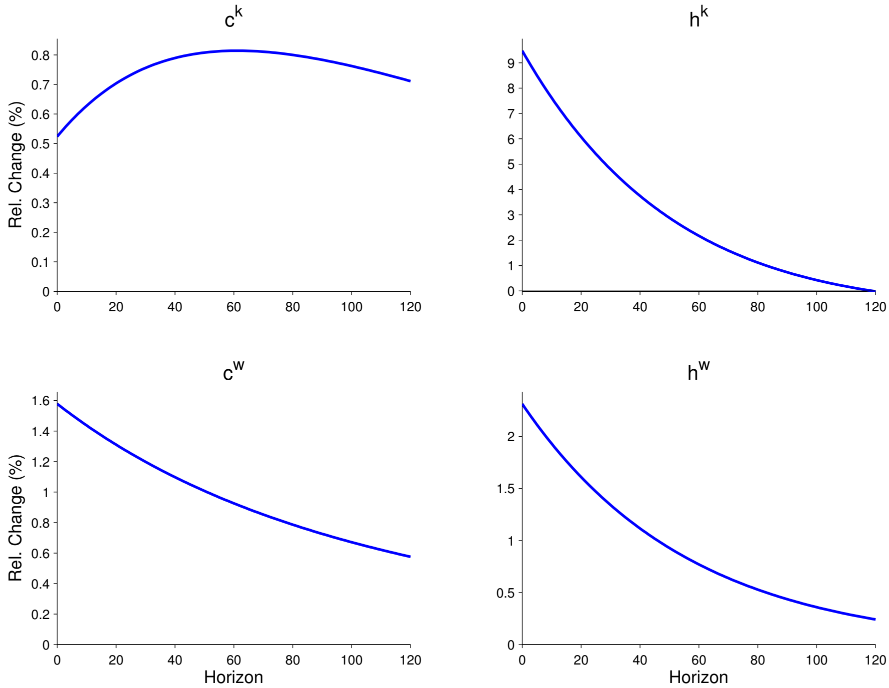
Qualitatively, both types of households react similarly to a positive shock to the labor wedge. In particular, both agents increase their labor supply and level of consumption. Quantitatively however we observe differences. While the labor supply response of the capitalist is quite pronounced, the worker's consumption response outperforms the one of the capitalist.

4.4.4 Model Generated Time Series

Exogenous State Variables

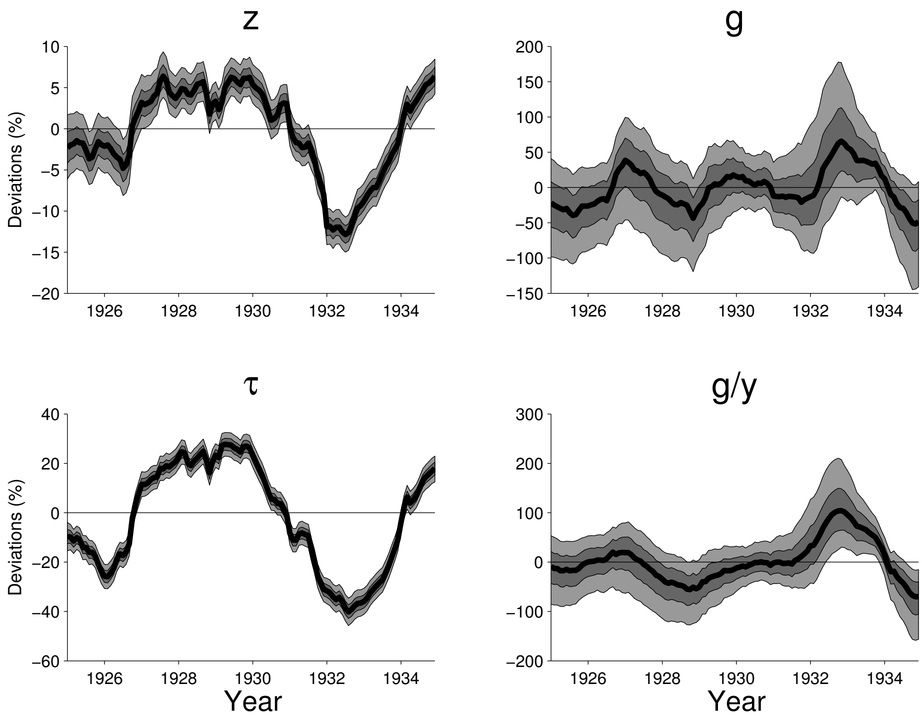
In this section we present model generated time series of the unobservable state variables. For this purpose, we draw 5,000 times from the posterior distribution, solve the model, and generate smoothed time series of the exogenous state

Figure 4.7: Impulse Responses (τ_t–Shock): Heterogeneous Agents



Notes: Impulse responses to a one standard deviation shock evaluated at the median of the posterior distribution.

Figure 4.8: Model Generated State Variables



Notes: Results are based on 5,000 draws from the posterior distribution. Light–gray shaded area represents 95% probability bands, dark–gray shaded area represents 68% probability bands, black line represents median.

variables using the Kalman filter. Results are presented in Figure 4.8.

We find that the evolution of the level of TFP coincides with the pattern of output. That is, it starts to severely deteriorate after 1929, with a lower turning point around 1932 and a strong recovery thereafter. Hence, we confirm the results of Fisher and Hornstein (2002), who also detect a strong procyclicality of productivity. Admittedly, variations in TFP yield a wide range of interpretations. Taking it literally, a decrease would translate into period of technical regress, which might not have been a major reason for the economic downturn. However, as we do not explicitly model a financial channel, a decrease in TFP could capture an increase in inefficiencies in the financial intermediation sector along the lines of Bernanke (1983). In particular, he points out the strong negative effects on the real economy during the Great Depression caused by escalating costs of credit intermediation. As Germany was severely hit by a banking crisis in 1931, such an explanation would coincide with the observed deterioration of TFP intensifying after 1931.

The evolution of the labor wedge follows a similar pattern.Note that the labor wedge was about 20 percent above steady state from 1927–1930 which is in line with the interpretation of Borchardt (1982) that the labor market suffered severe structural problems prior to the Great Depression. Moreover, during the contractionary phase the labor wedge deteriorated. Parts of the decrease could be attributed to to Brünings wage cuts enforced by emergency decrees. This result is also in line with Shimer (2009), who finds that for the case of the US economy inefficiencies on the labor market tend to increase during recessions.

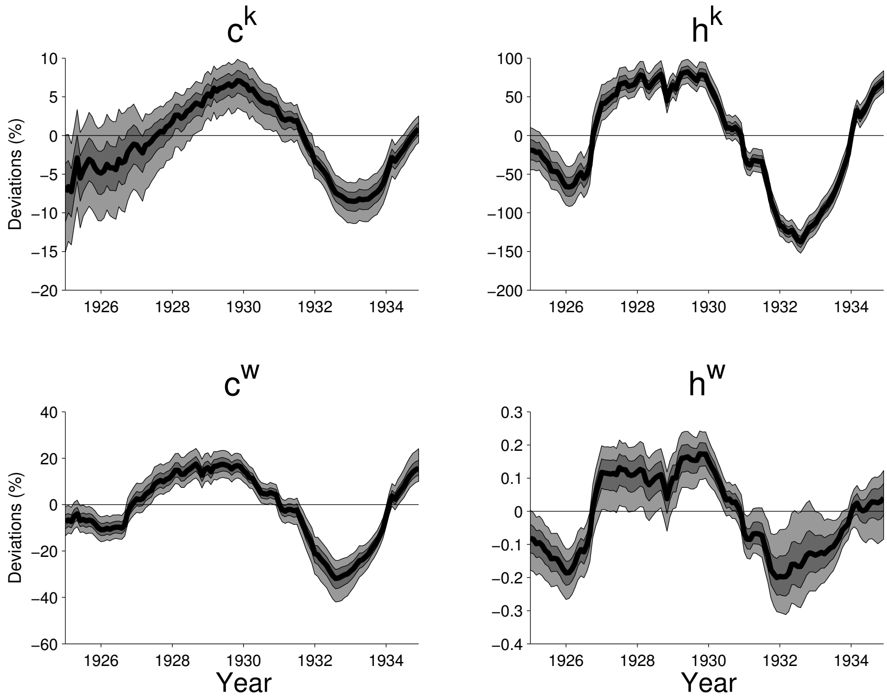
The amount of government expenditure is complemented by a plot characterizing the implied public expenditure quota. Interestingly, we observe a sharp increase after 1932. In 1933, the public expenditure quota reached deviations of up to 100 percent. This captures well the demand side policies of the NSDAP being in place, while the economy was still in a depression. Hence, we identify expansionary fiscal policy shocks after 1932/33. However, it clearly did not suffice to fully stabilize the economy.

We do not observe a lot of uncertainty with respect to the evolution of TFP and the labor wedge, as the the probability bands are rather narrow. This does not hold true for the case of government expenditure, where we clearly see a larger degree of uncertainty.

Heterogeneous Agents

Figure 4.9 depicts estimated time series of capitalists's and workers level of consumption and labor supply.

Figure 4.9: Model Generated Control Variables



Notes: Results are based on 5,000 draws from the posterior distribution. Light–gray shaded area represents 95% probability bands, dark–gray shaded area represents 68% probability bands, black line represents median.

We observe that the qualitative implications for capitalists and workers were similar. That is, both suffered a decline in consumption and reduced their level of labor supply. In quantitative terms however one can point out that the level of consumption of the capitalist varied far less than the one of the worker. This is probably due to the fact that they could use asset markets to sustain a more smoothed consumption path, while workers on the other hand simply had to cut their level of consumption during bad times. Concerning the labor supply response we find that capitalists reacted in a far more volatile way. This may also be attributed to the fact that labor income is not their only source of income.

We have seen that the labor wedge deteriorated during the Great Depression (see Figure 4.8), thus capitalists reduced their amount of labor supply and could use other sources of income instead. Hence, workers were in general more vulnerable compared to capitalists.

4.4.5 Business Cycle Accounting

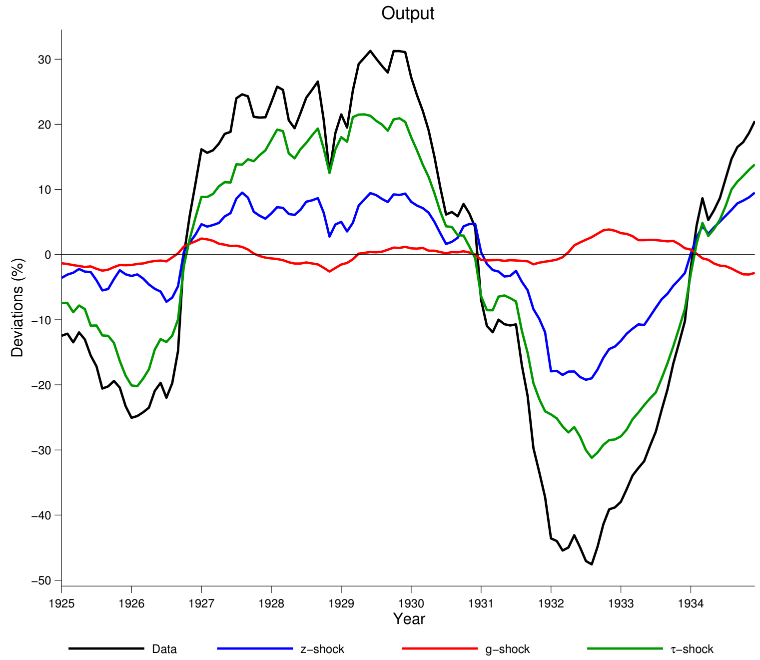
Output

In this section we look at the contribution of each shock to the observed time series. In particular, we draw 5,000 times from the posterior distribution, simulate the model, and recover the smoothed time series of the exogenous states using the Kalman filter. Thereafter, we compute our control and endogenous state variables in four different ways: (i) using all shocks[18] (ii) only using the z_t–shock time series (iii) only using the g_t–shock time series (iv) only using the τ_t–shock time series. For the cases (ii)–(iv) the remaining exogenous processes are assumed to be in equilibrium throughout the whole period. Note that the result of (i) is equal to the sum of (ii)–(iv), since the resulting time series are a linear combinations of the exogenous shock contributions. Thus, such a business cycle accounting approach represents a straightforward way of decomposing variations in the observable variables into contributions of the exogenous shocks. Figure 4.10 presents the outcome for output.

We clearly observe that the labor wedge was playing a dominant role for the evolution of German output during the Interwar Period. This underpins the structural problems, or even *sickness* of the economy, as pointed out by Borchardt (1982). Also TFP played a significant role in driving output. Both shock time series seem to be highly correlated with the business cycle of output. Government spending on the contrary did not play a major role. This interpretation is in line with the forecast error variance analysis of Section 4.4.2. Interestingly, we can again detect a positive contribution of government spending in 1932/33, resulting in a positive deviation of output of about 5 percent. This again confirms the fact

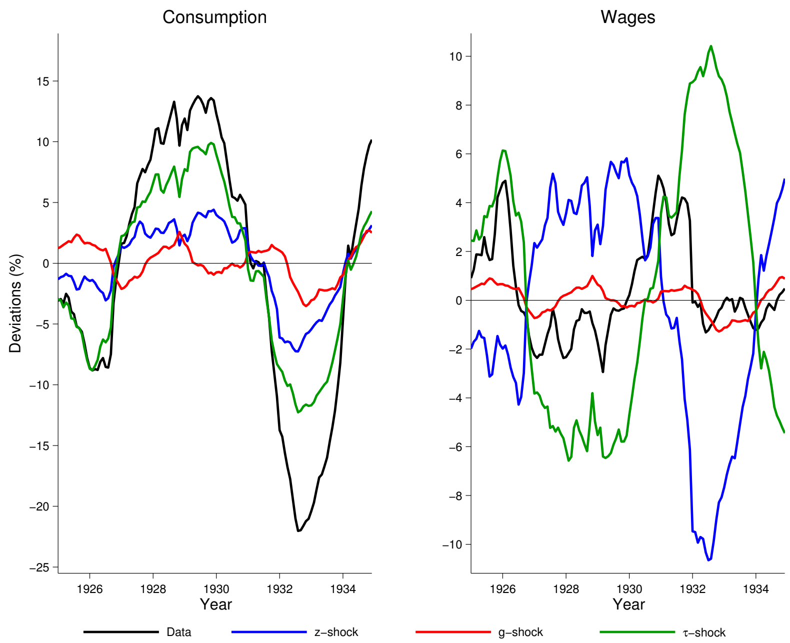
[18]Note that for the case of our observable control variables, we match the data perfectly. For variables not used for the estimation, we generate a model implied time series, which we use as a benchmark.

Figure 4.10: Decomposition of Output Cycle



Notes: Black line corresponds to actual stationary output data. Blue line, red line, and green line depict counterfactual model generated data by only considering TFP shocks, government expenditure shocks, or labor wedge shocks, respectively. Results are based on 5,000 draws from the posterior distribution. Median outcomes are reported.

Figure 4.11: Decomposition of Consumption and Wage Cycle



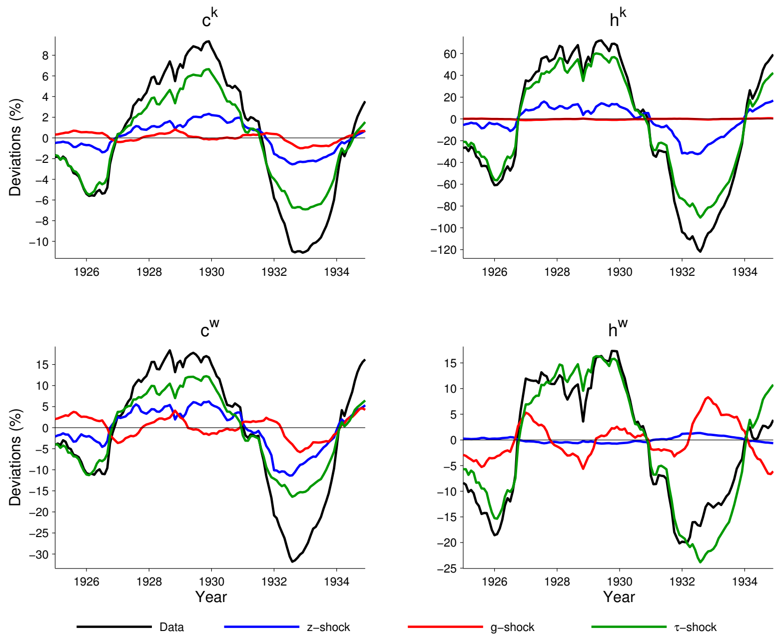
Notes: Black line corresponds to actual stationary consumption or wage data, respectively. Blue line, red line, and green line depict counterfactual model generated data by only considering TFP shocks, government expenditure shocks, or labor wedge shocks, respectively. Results are based on 5,000 draws from the posterior distribution. Median outcomes are reported.

that government expenditure was expansionary at that time, but not sufficient to explain the full recovery of the economy. Even a doubling of the public expenditure would not have sufficed. Thus, any suggested public expenditure programs discussed at that time would have yielded minor effects.

Consumption and Wages

The pattern for consumption is similar to the one of output. The only remarkable difference is that government expenditure was more important. This does not hold true for the case of wages, where the picture is strikingly different. In fact, TFP and the labor wedge seem to affect the evolution of the real wage in opposing directions. Focusing on the Great Depression, we observe in the data a downturn in wages relative to the trend occurring in 1932. This coincides with Brünings emergency decree's, including wage cuts. The strong positive effect of the labor wedge is accompanied by downwards pressure on the wage caused by a deterioration in TFP. Likewise, we can observe that the sharp increase of the real wage from 1929 to 1931 can be attributed to shocks to the labor wedge and TFP.

Figure 4.12: Decomposition of the Cycle of Further Control Variables



Notes: Black line corresponds to model generated data. Blue line, red line, and green line depict counterfactual model generated data by only considering TFP shocks, government expenditure shocks, or labor wedge shocks, respectively. Results are based on 5,000 draws from the posterior distribution. Median outcomes are reported.

Heterogeneous Agents

Lastly, we do the same exercise for model generated data of c^k, h^k, c^w, and h^w and depict the results in Figure 4.12.

We find a dominant role of the labor wedge in explaining dynamics. In addition, we see that government expenditure shocks play a more important role for workers than for capitalists. In particular, we see a positive response of the worker's level of labor supply caused by government spending shocks occurring in 1932/33. This might be attributed to expansionary fiscal measures implemented by the NSDAP.

4.5 Conclusion

We develop a DSGE model to analyze the dynamics of the German economy during the Great Depression. Estimation results suggest that the model fits the data quite well. Hence, we take this as a result in favor of our model choice. Our findings support the views of Borchardt (1982) and Ritschl (2002). In particular, our analysis highlights that the German economy was characterized by severe labor market distortions and borrowing constraints during the Interwar Period, while the scope for expansionary demand side policies was rather limited. Moreover, this result is also in line with Fisher and Hornstein (2002), who also identifies overvalued real wages as the most important factor explaining the recession. Hence, Brüning could not have avoided the severe downturn of the economy, even if he had had the legal base and political support to implement debt–financed expansionary fiscal policies. Furthermore, we find that workers were disproportionately hit by the consequences of the economic downturn compared to capitalists.

Appendix A

Appendix to "Business Cycles in Emerging Markets: the Role of Liability Dollarization and Valuation Effects"

The following presents an extensive appendix to the paper "Business Cycles in Emerging Markets: the Role of Liability Dollarization and Valuation Effects".

A.1 Model

This section describes the model environment of our framework with liability dollarization.

A.1.1 Model Framework

The economy is represented by:

Production Technology

$$Y_t = z_t K_t^{\alpha} (\Gamma_t l_t)^{1-\alpha} \qquad \text{Production Function}$$

$$z_t = z_{t-1}^{\rho_z} \exp(\epsilon_t^z) \qquad \text{Transitory Technology Process}$$

$$\Gamma_t = g_t \Gamma_{t-1} = \prod_{s=0}^{t} g_s, \quad g_t = \mu_g^{1-\rho_g} g_{t-1}^{\rho_g} \exp(\epsilon_t^g) \qquad \text{Permanent Technology Process}$$

$$K_{t+1} = (1-\delta) K_t + I_t - \frac{\phi}{2} \left(\frac{K_{t+1}}{K_t} - \mu_g \right)^2 K_t \qquad \text{Law of Motion of Capital}$$

with $\epsilon_t^z \sim \mathcal{N}(0, \sigma_z^2)$ and $\epsilon_t^g \sim \mathcal{N}(0, \sigma_g^2)$.

Consumption

$$C_t = \left[\theta^{\frac{1}{\eta}} C_{H,t}^{\frac{\eta-1}{\eta}} + (1-\theta)^{\frac{1}{\eta}} C_{F,t}^{\frac{\eta-1}{\eta}} \right]^{\frac{\eta}{\eta-1}} \qquad \text{Consumption Index}$$

$$u(C_t, 1-l_t) = \frac{[C_t^{\gamma} (1-l_t)^{1-\gamma}]^{1-\sigma}}{1-\sigma} \qquad \text{Household Period Utility Function}$$

$$C_t^{\star} = (C^{\star})^{1-\rho_c} (C_{t-1}^{\star})^{\rho_c} \exp(\epsilon_t^c) \qquad \text{Foreign Consumption Process}$$

with $\epsilon_t^c \sim \mathcal{N}(0, \sigma_c^2)$.

Price Indices

$$e_t = \frac{p_t}{p_{F,t}} \qquad \text{Real Exchange Rate}$$

$$r_t = r + \psi \left(\exp \left(\mathrm{E}_t \left[\frac{p_{t+1} D_{t+1}}{e_{t+1} Y_{t+1}} \right] - \frac{pD}{eY} \right) - 1 \right) \qquad \text{Interest Rate}$$

$$p_t = \left[\theta p_{H,t}^{1-\eta} + (1-\theta) p_{F,t}^{1-\eta} \right]^{\frac{1}{1-\eta}} \qquad \text{Domestic Price Index}$$

$$tot_t = \frac{p_{H,t}}{p_{F,t}} \qquad \text{Terms of Trade}$$

Aggregation

$$Y_t + p_t \frac{D_{t+1}}{e_t} = p_t C_t + I_t + p_t \frac{D_t}{e_t}(1 + r_{t-1}) \qquad \text{Resource Constraint}$$

$$NX_t = p_{H,t} C^{\star}_{H,t} - p_{F,t} C_{F,t} \qquad \text{Net Exports}$$

$$CA_t = -r_{t-1} p_t \frac{D_t}{e_t} + NX_t \qquad \text{Current Account}$$

$$\Delta NFA_t = CA_t + VAL_t \qquad \text{Change in Net Foreign Asset Position}$$

$$VAL_t = D_t \left(\frac{p_{t-1}}{e_{t-1}} - \frac{p_t}{e_t} \right) \qquad \text{Valuation Effects}$$

$$Y_t = p_{H,t}(C_{H,t} + C^{\star}_{H,t} + I_t) \qquad \text{Good Market Clearing}$$

Since there is no population growth in this model, the mass of population is set equal to one. Moreover, the home–produced good serves as numéraire, i.e. we normalize its price $p_{H,t}$ to one. Accordingly, everything is expressed in units of the home good instead of the domestic currency.

A.1.2 Detrending the Variables

The variables Y_t, C_t, $C_{H,t}$, $C_{F,t}$, I_t, K_t, and D_t as well as $C^{\star}_{H,t}$ and $C^{\star}_t$ exhibit a common stochastic trend.[1] They need to be detrended in order to obtain system of stationary variables. Consequently, the relevant variables are detrended in the following way:

$$x_t \equiv \frac{X_t}{\Gamma_{t-1}},$$

where x_t denotes the stationary counterpart of X_t. Hence, our relevant equations in detrended form are given by

- Production Function

$$y_t = \frac{Y_t}{\Gamma_{t-1}} = \frac{z_t K_t^{\alpha} (\Gamma_t l_t)^{1-\alpha}}{\Gamma_{t-1}} = z_t k_t^{1-\alpha} (g_t l_t)^{\alpha}$$

[1] In general, foreign and domestic variables can exhibit different stochastic trends. However, to keep the model tractable, we assume that domestic and foreign variables share a cointegrating relationship with cointegraing vector $\beta = [1, -1]'$.

- Law of Motion of Capital

$$
\begin{aligned}
g_t k_{t+1} = \frac{\Gamma_t K_{t+1}}{\Gamma_t \Gamma_{t-1}} &= \frac{(1-\delta)K_t + I_t}{\Gamma_{t-1}} - \frac{\phi}{2}\left(\frac{K_{t+1}\Gamma_t}{\Gamma_t \Gamma_{t-1}}\frac{\Gamma_{t-1}}{K_t} - \mu_g\right)^2 \frac{K_t}{\Gamma_{t-1}} \\
&= (1-\delta)k_t + i_t - \frac{\phi}{2}\left(\frac{g_t k_{t+1}}{k_t} - \mu_g\right)^2 k_t
\end{aligned}
$$

- Consumption Index

$$
\begin{aligned}
c_t = \frac{C_t}{\Gamma_{t-1}} &= \frac{\left[\theta^{\frac{1}{\eta}} C_{H,t}^{\frac{\eta-1}{\eta}} + (1-\theta)^{\frac{1}{\eta}} C_{F,t}^{\frac{\eta-1}{\eta}}\right]^{\frac{\eta}{\eta-1}}}{\Gamma_{t-1}} \\
c_t &= \left[\theta^{\frac{1}{\eta}} \left(\frac{C_{H,t}}{\Gamma_{t-1}}\right)^{\frac{\eta-1}{\eta}} + (1-\theta)^{\frac{1}{\eta}} \left(\frac{C_{F,t}}{\Gamma_{t-1}}\right)^{\frac{\eta-1}{\eta}}\right]^{\frac{\eta}{\eta-1}} \\
c_t &= \left[\theta^{\frac{1}{\eta}} c_{H,t}^{\frac{\eta-1}{\eta}} + (1-\theta)^{\frac{1}{\eta}} c_{F,t}^{\frac{\eta-1}{\eta}}\right]^{\frac{\eta}{\eta-1}}.
\end{aligned}
$$

- Utility Function

$$
\begin{aligned}
u(C_t, 1-l_t) = \frac{(C_t^{\gamma}(1-l_t)^{1-\gamma})^{1-\sigma}}{1-\sigma} &= \frac{\Gamma_{t-1}^{\gamma(1-\sigma)}}{\Gamma_{t-1}^{\gamma(1-\sigma)}} \frac{(C_t^{\gamma}(1-l_t)^{1-\gamma})^{1-\sigma}}{1-\sigma} \\
&= \Gamma_{t-1}^{\gamma(1-\sigma)} \frac{\left(\left(\frac{C_t}{\Gamma_{t-1}}\right)^{\gamma}(1-l_t)^{1-\gamma}\right)^{1-\sigma}}{1-\sigma} \\
&= \underbrace{\Gamma_{t-1}^{\gamma(1-\sigma)}}_{\equiv \kappa_{t-1}} \underbrace{\frac{(c_t^{\gamma}(1-l_t)^{1-\gamma})^{1-\sigma}}{1-\sigma}}_{u(c_t, 1-l_t)} \\
&= \kappa_{t-1} u(c_t, 1-l_t)
\end{aligned}
$$

- Resource Constraint

$$
y_t = \frac{Y_t}{\Gamma_{t-1}} = \frac{p_t C_t + I_t + p_t \frac{D_t}{e_t}(1+r_{t-1})}{\Gamma_{t-1}} - \frac{\Gamma_t p_t \frac{D_{t+1}}{e_t}}{\Gamma_{t-1}\Gamma_t} = p_t c_t + i_t + p_t \frac{d_t}{e_t}(1+r_{t-1}) - g_t p_t \frac{d_{t+1}}{e_t}
$$

A.1.3 Maximization Problem of the Household

The optimization problem of the representative household can be decomposed into two stages. The first stage describes the *intratemporal* optimization problem and derives optimal consumption of home and foreign goods. The second stage is the *intertemporal* optimization problem, which determines the optimal intertemporal consumption and saving behavior.

First Stage – Intratemporal Optimization

The detrended consumption index is given by

$$c_t = \left[\theta^{\frac{1}{\eta}} c_{H,t}^{\frac{\eta-1}{\eta}} + (1-\theta)^{\frac{1}{\eta}} c_{F,t}^{\frac{\eta-1}{\eta}}\right]^{\frac{\eta}{\eta-1}},$$

where $c_{H,t}$ denotes detrended consumption of the home good, $c_{F,t}$ denotes detrended consumption of the foreign good, $\theta \in (0,1)$ is the share of home goods in consumption, and $\eta \in (0,\infty)$ is the elasticity of intratemporal substitution between home and foreign goods.

The price index p_t is defined as the minimum expenditure required to buy one unit of the detrended composite good c_t, given the prices of the home and foreign goods. Accordingly, the representative agent solves the minimization problem

$$\begin{aligned} \min_{\{c_{H,t}, c_{F,t}\}} \quad & p_t c_t = p_{H,t} c_{H,t} + p_{F,t} c_{F,t} \\ \text{s.t.} \qquad & c_t = \left[\theta^{\frac{1}{\eta}} c_{H,t}^{\frac{\eta-1}{\eta}} + (1-\theta)^{\frac{1}{\eta}} c_{F,t}^{\frac{\eta-1}{\eta}}\right]^{\frac{\eta}{\eta-1}} = 1. \end{aligned}$$

We set up the Lagrangian

$$\mathcal{L} = p_{H,t} c_{H,t} + p_{F,t} c_{F,t} - p_t \left[c_t - 1\right],$$

where we can use p_t as the Lagrange multiplier because it determines the shadow price of consumption. First–order conditions can then be derived as

$$\begin{aligned} \frac{\partial \mathcal{L}}{\partial c_{H,t}} = p_{H,t} - p_t \left(\frac{\eta}{\eta-1}\right) \left[\theta^{\frac{1}{\eta}} c_{H,t}^{\frac{\eta-1}{\eta}} + (1-\theta)^{\frac{1}{\eta}} c_{F,t}^{\frac{\eta-1}{\eta}}\right]^{\frac{\eta}{\eta-1}-1} \theta^{\frac{1}{\eta}} \left(\frac{\eta-1}{\eta}\right) c_{H,t}^{\frac{\eta-1}{\eta}-1} = 0 \\ \Leftrightarrow \qquad p_{H,t} = p_t c_t^{\frac{1}{\eta}} \theta^{\frac{1}{\eta}} c_{H,t}^{-\frac{1}{\eta}} \end{aligned}$$

and

$$\frac{\partial \mathcal{L}}{\partial c_{F,t}} = p_{F,t} - p_t \left(\frac{\eta}{\eta - 1}\right) \left[\theta^{\frac{1}{\eta}} c_{H,t}^{\frac{\eta-1}{\eta}} + (1-\theta)^{\frac{1}{\eta}} c_{F,t}^{\frac{\eta-1}{\eta}}\right]^{\frac{\eta}{\eta-1}-1} (1-\theta)^{\frac{1}{\eta}} \left(\frac{\eta-1}{\eta}\right) c_{F,t}^{\frac{\eta-1}{\eta}-1} = 0$$

$$\Leftrightarrow \qquad p_{F,t} = p_t c_t^{\frac{1}{\eta}} (1-\theta)^{\frac{1}{\eta}} c_{F,t}^{-\frac{1}{\eta}}.$$

Hence, we get

$$\begin{aligned} c_{H,t} &= \theta \left(\frac{p_t}{p_{H,t}}\right)^{\eta} c_t \\ c_{F,t} &= (1-\theta) \left(\frac{p_t}{p_{F,t}}\right)^{\eta} c_t. \end{aligned}$$

Note that we can combine and rearrange the above equations for $c_{H,t}$ and $c_{F,t}$ to obtain

$$\frac{c_{H,t}}{c_{F,t}} = \frac{\theta}{1-\theta} \left(\frac{p_{H,t}}{p_{F,t}}\right)^{-\eta}.$$

From this equation, we can easily show that the elasticity of intratemporal substitution between home and foreign consumption goods is given by η:

$$\frac{\mathrm{d}\ \log\left(\frac{c_{H,t}}{c_{F,t}}\right)}{\mathrm{d}\ \log\left(\frac{p_{H,t}}{p_{F,t}}\right)} = -\eta,$$

i.e. if the relative price of home consumption increases by 1 percent, relative home consumption declines by η percent.

As a next step, we derive the consumption price index p_t:

$$\begin{aligned} p_t c_t &= p_{H,t} c_{H,t} + p_{F,t} c_{F,t} \\ \Leftrightarrow \quad p_t c_t &= p_{H,t} \theta \left(\frac{p_t}{p_{H,t}}\right)^{\eta} c_t + p_{F,t}(1-\theta) \left(\frac{p_t}{p_{F,t}}\right)^{\eta} c_t \\ \Leftrightarrow \quad p_t &= \theta p_t^{\eta} p_{H,t}^{1-\eta} + (1-\theta) p_t^{\eta} p_{F,t}^{1-\eta} \\ \Leftrightarrow \quad p_t^{1-\eta} &= \theta p_{H,t}^{1-\eta} + (1-\theta) p_{F,t}^{1-\eta} \\ \Leftrightarrow \quad p_t &= \left[\theta p_{H,t}^{1-\eta} + (1-\theta) p_{F,t}^{1-\eta}\right]^{\frac{1}{1-\eta}}. \end{aligned}$$

Since we normalize the price of home goods to one, our equations determining the consumption of home goods and the price index simplify to

$$
\begin{aligned}
c_{H,t} &= \theta p_t^{\eta} c_t \\
p_t &= \left[\theta + (1-\theta) p_{F,t}^{1-\eta}\right]^{\frac{1}{1-\eta}} .
\end{aligned}
$$

Second Stage – Intertemporal Optimization

Combining the detrended versions of production, law of motion of capital, and the resource constraint yields the aggregate resource constraint of the economy as a function of capital, labor, consumption and foreign debt. As a result, the representative household's optimization problem at time t can be stated as

$$
\begin{aligned}
&\max_{\{c_\tau, l_\tau, k_{\tau+1}, d_{\tau+1}\}} \mathrm{E}_t \sum_{\tau=t}^{\infty} \beta^{\tau-t} (\kappa_{\tau-1} u(c_\tau, 1-l_\tau)) \\
\text{s.t.} \quad & z_\tau k_\tau^{1-\alpha} (g_\tau l_\tau)^\alpha + (1-\delta) k_\tau + g_\tau p_\tau \frac{d_{\tau+1}}{e_\tau} \geq \\
& \qquad p_\tau c_\tau + g_\tau k_{\tau+1} + \frac{\phi}{2} \left(g_\tau \frac{k_{\tau+1}}{k_\tau} - \mu_g \right)^2 k_\tau + p_\tau \frac{d_\tau}{e_\tau} (1 + r_{\tau-1}),
\end{aligned}
$$

taking as given k_t, d_t, as well as the transversality condition $\lim_{j\to\infty} \mathrm{E}_t \left[\prod_{s=0}^{j-2} \frac{d_{t+j}}{1+r_{t+s}} \right] = 0$. Accordingly, the optimization problem yields the following Lagrangian:

$$
\begin{aligned}
\mathcal{L} = &\mathrm{E}_t \Bigg[\sum_{\tau=t}^{\infty} \beta^{\tau-t} \Bigg(\kappa_{\tau-1} u(c_\tau, 1-l_\tau) + \lambda_\tau \Bigg(z_\tau k_\tau^{1-\alpha} (g_\tau l_\tau)^\alpha + g_\tau p_\tau \frac{d_{\tau+1}}{e_\tau} + (1-\delta) k_\tau \\
&- p_\tau c_\tau - g_\tau k_{\tau+1} - \frac{\phi}{2} \left(g_\tau \frac{k_{\tau+1}}{k_\tau} - \mu_g \right)^2 k_\tau - p_\tau \frac{d_\tau}{e_\tau} (1 + r_{\tau-1}) \Bigg) \Bigg) \Bigg]
\end{aligned}
$$

with the following first order conditions:

$$
\begin{aligned}
&\text{(I)} && \frac{\partial \mathcal{L}}{\partial c_t} = \kappa_{t-1}\frac{\partial u(c_t, 1-l_t)}{\partial c_t} - \lambda_t p_t = 0 \\
& \Leftrightarrow && \kappa_{t-1}\frac{\partial u(c_t, 1-l_t)}{\partial c_t} = \lambda_t p_t \\
& \Rightarrow && \kappa_t \mathrm{E}_t\left[\frac{\partial u(c_{t+1}, 1-l_{t+1})}{\partial c_{t+1}}\right] = \mathrm{E}_t\left[\lambda_{t+1}p_{t+1}\right] \\
&\text{(II)} && \frac{\partial \mathcal{L}}{\partial l_t} = \kappa_{t-1}\frac{\partial u(c_t, 1-l_t)}{\partial l_t} + \lambda_t\frac{\partial y_t}{\partial l_t} = 0 \\
& \Leftrightarrow && -\kappa_{t-1}\frac{\partial u(c_t, 1-l_t)}{\partial l_t} = \lambda_t\frac{\partial y_t}{\partial l_t} \\
&\text{(III)} && \frac{\partial \mathcal{L}}{\partial k_{t+1}} = -\lambda_t\left[g_t\left(1+\phi\left(g_t\frac{k_{t+1}}{k_t} - \mu_g\right)\right)\right] + \mathrm{E}_t\Bigg[\beta\lambda_{t+1}\Bigg(\frac{\partial y_{t+1}}{\partial k_{t+1}} \\
& && + (1-\delta) + \phi\left(g_{t+1}\frac{k_{t+2}}{k_{t+1}} - \mu_g\right)g_{t+1}\frac{k_{t+2}}{k_{t+1}} - \frac{\phi}{2}\left(g_{t+1}\frac{k_{t+2}}{k_{t+1}} - \mu_g\right)^2\Bigg)\Bigg] = 0 \\
& \Leftrightarrow && \lambda_t\left[g_t\left(1+\phi\left(g_t\frac{k_{t+1}}{k_t} - \mu_g\right)\right)\right] = \mathrm{E}_t\Bigg[\beta\lambda_{t+1}\Bigg(\frac{\partial y_{t+1}}{\partial k_{t+1}} \\
& && + (1-\delta) + \phi\left(g_{t+1}\frac{k_{t+2}}{k_{t+1}} - \mu_g\right)g_{t+1}\frac{k_{t+2}}{k_{t+1}} - \frac{\phi}{2}\left(g_{t+1}\frac{k_{t+2}}{k_{t+1}} - \mu_g\right)^2\Bigg)\Bigg] \\
&\text{(IV)} && \frac{\partial \mathcal{L}}{\partial d_{t+1}} = \lambda_t g_t\frac{p_t}{e_t} - \beta\mathrm{E}_t\left[\lambda_{t+1}\frac{p_{t+1}}{e_{t+1}}(1+r_t)\right] = 0 \\
& \Leftrightarrow && \lambda_t g_t\frac{p_t}{e_t} = \beta\mathrm{E}_t\left[\lambda_{t+1}\frac{p_{t+1}}{e_{t+1}}(1+r_t)\right] \\
&\text{(V)} && \frac{\partial \mathcal{L}}{\partial \lambda_t} = y_t + (1-\delta)k_t + p_t\frac{g_t d_{t+1}}{e_t} \\
& && - c_t - g_t k_{t+1} - \frac{\phi}{2}\left(g_t\frac{k_{t+1}}{k_t} - \mu_g\right)^2 k_t - p_t\frac{d_t}{e_t}(1+r_{t-1}) = 0 \\
& \Leftrightarrow && y_t + (1-\delta)k_t + p_t\frac{g_t d_{t+1}}{e_t} = \\
& && p_t c_t + g_t k_{t+1} + \frac{\phi}{2}\left(g_t\frac{k_{t+1}}{k_t} - \mu_g\right)^2 k_t + p_t\frac{d_t}{e_t}(1+r_{t-1})
\end{aligned}
$$

A.1.4 International Prices and Trade

The representative agent's problem in the rest of the world is analogous to the home country. However, the domestic economy is infinitesimally small. That is, the rest of the world is approximately closed and only consumes goods produced abroad. Accordingly, the price index of the foreign consumption composite $p_t^\star$ boils down to the foreign price of goods produced in the rest of the world $p_{F,t}^\star$, i.e.

$p_t^\star = p_{F,t}^\star$. We assume that the law of one price holds:

$$p_{F,t} = \frac{p_{F,t}^\star}{s_t} = \frac{p_t^\star}{s_t},$$

and

$$p_{H,t} = \frac{p_{H,t}^\star}{s_t},$$

where s_t represents the nominal exchange rate defined as the price of the domestic currency in terms of the foreign currency. Since the domestic price of home goods is normalized to one, the nominal exchange rate simply equals the foreign price of home goods $p_{H,t}^\star$. The real exchange rate is the price of the domestic composite consumption good in units of the foreign composite consumption good:[2]

$$e_t = \frac{p_t s_t}{p_t^\star} = \frac{p_t s_t}{p_{F,t}^\star} = \frac{p_t s_t}{p_{F,t} s_t} = \frac{p_t}{p_{F,t}}.$$

Terms of trade are defined as the price of home–produced goods in terms of imported foreign goods:

$$tot_t = \frac{p_{H,t}}{p_{F,t}} = \frac{1}{p_{F,t}}.$$

Let $c_t^\star$ denote detrended foreign consumption. We assume that the rest of the world has the same composite consumption index as the domestic economy. Hence, from the perspective of the home economy, foreign demand for the home

[2]Despite the assumption that the law of one price holds for our individual goods, purchasing power parity is not fulfilled. Thus, the real exchange rate is not equal to one in our setup. At first glance, this seems somewhat bewildering. However, not that the home country is infinitesimally small from the viewpoint of the rest of the world such that foreign composite consumption consists only of foreign goods. Therefore, we generally have $p_t s_t \neq p_t^\star$ and $e_t \neq 1$. Monacelli (2005) calls this the "law of one price gap".

good is given by

$$
\begin{aligned}
& c^{\star}_{H,t} = \theta^{\star} \left(\frac{p^{\star}_t}{p^{\star}_{H,t}} \right)^{\eta^{\star}} c^{\star}_t \\
\Leftrightarrow \quad & c^{\star}_{H,t} = \theta^{\star} \left(\frac{p^{\star}_{F,t}}{p^{\star}_{H,t}} \right)^{\eta^{\star}} c^{\star}_t \\
\Leftrightarrow \quad & c^{\star}_{H,t} = \theta^{\star} \left(\frac{p_{F,t} s_t}{p_{H,t} s_t} \right)^{\eta^{\star}} c^{\star}_t \\
\Leftrightarrow \quad & c^{\star}_{H,t} = \theta^{\star} \left(\frac{p_{F,t}}{p_{H,t}} \right)^{\eta^{\star}} c^{\star}_t \\
\Leftrightarrow \quad & c^{\star}_{H,t} = \theta^{\star} \left(\frac{1}{tot_t} \right)^{\eta^{\star}} c^{\star}_t \\
\Leftrightarrow \quad & c^{\star}_{H,t} = \theta^{\star} p_{F,t}^{\eta^{\star}} c^{\star}_t .
\end{aligned}
$$

Imports are given by $p_{F,t} c_{F,t}$, such that net exports can be calculated as

$$nx_t = p_{H,t} c^{\star}_{H,t} - p_{F,t} c_{F,t} = c^{\star}_{H,t} - p_{F,t} c_{F,t}.$$

A.1.5 Current Account and Valuation Effects

The change in the net foreign asset position equals the current account adjusted for valuation effects:

$$\Delta NFA_t = CA_t + VAL_t.$$

It is straightforward to derive valuation effects in this model. The current account is equal to the sum of negative interest payments on foreign debt and net exports:

$$CA_t = -r_{t-1} p_t \frac{D_t}{e_t} + NX_t.$$

Also, recall that the aggregate resource constraint given by

$$Y_t + p_t \frac{D_{t+1}}{e_t} = p_t C_t + I_t + p_t \frac{D_t}{e_t} (1 + r_{t-1}).$$

We can then rearrange the resource constraint to get

$$
\begin{aligned}
& Y_t - p_t C_t - I_t - r_{t-1} p_t \frac{D_t}{e_t} = p_t \left(-\frac{D_{t+1}}{e_t} + \frac{D_t}{e_t} \right) \\
\Leftrightarrow \quad & \underbrace{Y_t - p_t C_t - I_t}_{= \text{Primary Current Account}} - r_{t-1} p_t \frac{D_t}{e_t} = -p_t \frac{D_{t+1}}{e_t} + p_t \frac{D_t}{e_t} - p_{t-1} \frac{D_t}{e_{t-1}} + p_{t-1} \frac{D_t}{e_{t-1}} \\
\Leftrightarrow \quad & \underbrace{Y_t - I_t}_{= \text{Net Output}} \underbrace{- p_{H,t} C_{H,t} - p_{F,t} C_{F,t}}_{= -p_t C_t} - r_{t-1} p_t \frac{D_t}{e_t} = \underbrace{-p_t \frac{D_{t+1}}{e_t} + p_{t-1} \frac{D_t}{e_{t-1}}}_{= \Delta NFA_t} + p_t \frac{D_t}{e_t} - p_{t-1} \frac{D_t}{e_{t-1}} \\
\Leftrightarrow \quad & \underbrace{p_{H,t} C^\star_{H,t} + p_{H,t} C_{H,t} + I_t}_{= Y_t \text{ by good market equilibrium}} - I_t - p_{H,t} C_{H,t} - p_{F,t} C_{F,t} - r_{t-1} p_t \frac{D_t}{e_t} \\
& = \Delta NFA_t + p_t \frac{D_t}{e_t} - p_{t-1} \frac{D_t}{e_{t-1}} \\
\Leftrightarrow \quad & \underbrace{p_{H,t} C^\star_{H,t} - p_{F,t} C_{F,t}}_{= NX_t} - r_{t-1} p_t \frac{D_t}{e_t} - p_t \frac{D_t}{e_t} + p_{t-1} \frac{D_t}{e_{t-1}} = \Delta NFA_t \\
\Leftrightarrow \quad & \Delta NFA_t = NX_t - r_{t-1} p_t \frac{D_t}{e_t} + \underbrace{D_t \left(\frac{p_{t-1}}{e_{t-1}} - \frac{p_t}{e_t} \right)}_{= VAL_t} \\
\Leftrightarrow \quad & \Delta NFA_t = CA_t + VAL_t.
\end{aligned}
$$

Hence, valuation effects are given by

$$
VAL_t = D_t \left(\frac{p_{t-1}}{e_{t-1}} - \frac{p_t}{e_t} \right).
$$

Next, we take a look at the current account, net foreign asset position and valuation effects in stationary form. Let us first consider the current account:

$$
\begin{aligned}
& ca_t = \frac{CA_t}{\Gamma_{t-1}} = -r_{t-1} p_t \frac{D_t}{\Gamma_{t-1} e_t} + \frac{NX_t}{\Gamma_{t-1}} \\
\Leftrightarrow \quad & ca_t = -r_{t-1} p_t \frac{d_t}{e_t} + p_{H,t} \frac{C^\star_{H,t} \Gamma^\star_{t-1}}{\Gamma_{t-1} \Gamma^\star_{t-1}} - p_{F,t} \frac{C_{F,t}}{\Gamma_{t-1}} \\
\Leftrightarrow \quad & ca_t = -r_{t-1} p_t \frac{d_t}{e_t} + p_{H,t} \frac{C^\star_{H,t} \Gamma^\star_{t-1}}{\Gamma_{t-1} \Gamma^\star_{t-1}} - p_{F,t} c_{F,t} \\
\Leftrightarrow \quad & ca_t = -r_{t-1} p_t \frac{d_t}{e_t} + p_{H,t} c^\star_{H,t} \underbrace{\frac{\Gamma^\star_{t-1}}{\Gamma_{t-1}}}_{=1} - p_{F,t} c_{F,t}
\end{aligned}
$$

$$\Leftrightarrow \qquad ca_t = -r_{t-1}p_t\frac{d_t}{e_t} + p_{H,t}c^{\star}_{H,t} - p_{F,t}c_{F,t}$$
$$\Leftrightarrow \qquad ca_t = -r_{t-1}p_t\frac{d_t}{e_t} + nx_t,$$

where we use the assumption that both the domestic small open economy and the rest of the world share a common stochastic trend component: $\Gamma_{t-1} = \Gamma^{\star}_{t-1}$.The stationary expression for the change in the net foreign asset position is given by

$$\frac{\Delta NFA_t}{\Gamma_{t-1}} = -\frac{D_{t+1}}{\Gamma_t}\frac{\Gamma_t}{\Gamma_{t-1}}\frac{p_t}{e_t} + \frac{D_t}{\Gamma_{t-1}}\frac{p_{t-1}}{e_{t-1}}$$
$$\Delta nfa_t = -g_t p_t\frac{d_{t+1}}{e_t} + p_{t-1}\frac{d_t}{e_{t-1}}.$$

Finally, detrended valuation effects can be derived as

$$\frac{VAL_t}{\Gamma_{t-1}} = \frac{D_t}{\Gamma_{t-1}}\left(\frac{p_{t-1}}{e_{t-1}} - \frac{p_t}{e_t}\right)$$
$$val_t = d_t\left(\frac{p_{t-1}}{e_{t-1}} - \frac{p_t}{e_t}\right).$$

A.1.6 Model Summary

Eventually, we can summarize our model, which is described by the following optimality and necessary conditions:

- Production Function

$$y_t = z_t k_t^{\alpha}(g_t l_t)^{1-\alpha} \tag{A.1}$$

- Period t Resource Constraint

$$y_t = p_t c_t + i_t + p_t\frac{d_t}{e_t}(1 + r_{t-1}) - p_t\frac{g_t d_{t+1}}{e_t} \tag{A.2}$$

- Law of Motion of Capital

$$g_t k_{t+1} = (1-\delta)k_t + i_t - \frac{\phi}{2}\left(\frac{g_t k_{t+1}}{k_t} - \mu_g\right)^2 k_t \tag{A.3}$$

- Investment Euler Equation

$$\frac{\partial u(c_t, 1-l_t)}{\partial c_t}\left(1+\phi\left(g_t\frac{k_{t+1}}{k_t}-\mu_g\right)\right) = g_t^{\gamma(1-\sigma)-1}\beta \mathrm{E}_t\Bigg[\frac{p_t}{p_{t+1}}\frac{\partial u(c_{t+1}, 1-l_{t+1})}{\partial c_{t+1}}$$
$$\left(\frac{\partial y_{t+1}}{\partial k_{t+1}} + (1-\delta) + \phi\left(g_{t+1}\frac{k_{t+2}}{k_{t+1}}-\mu_g\right)g_{t+1}\frac{k_{t+2}}{k_{t+1}} - \frac{\phi}{2}\left(g_{t+1}\frac{k_{t+2}}{k_{t+1}}-\mu_g\right)^2\right)\Bigg] \tag{A.4}$$

- Labor–Leisure Trade–off

$$-p_t\frac{\partial u(c_t, 1-l_t)}{\partial l_t} = \frac{\partial u(c_t, 1-l_t)}{\partial c_t}\frac{\partial y_t}{\partial l_t} \tag{A.5}$$

- Bond Euler Equation

$$\frac{\partial u(c_t, l_t)}{\partial c_t} = g_t^{\gamma(1-\sigma)-1}\beta \mathrm{E}_t\left[\frac{\partial u(c_{t+1}, l_{t+1})}{\partial c_{t+1}}\frac{e_t}{e_{t+1}}(1+r_t)\right] \tag{A.6}$$

- Interest Rate

$$r_t = r + \psi\left(\exp\left(\mathrm{E}_t\left[\frac{p_{t+1}d_{t+1}}{e_{t+1}y_{t+1}}\right] - \frac{pd}{ey}\right) - 1\right) \tag{A.7}$$

- Consumption of the Home Good

$$c_{H,t} = \theta p_t^{\eta} c_t \tag{A.8}$$

- Consumption of the Foreign Good

$$c_{F,t} = (1-\theta)\left(\frac{p_t}{p_{F,t}}\right)^{\eta} c_t \tag{A.9}$$

- Price of Consumption

$$p_t = \left[\theta + (1-\theta)p_{F,t}^{1-\eta}\right]^{\frac{1}{1-\eta}} \tag{A.10}$$

- Exchange Rate

$$e_t = \frac{p_t}{p_{F,t}} \tag{A.11}$$

- Exports of Home Goods

$$c^{\star}_{H,t} = \theta^{\star} p^{\eta^{\star}}_{F,t} c^{\star}_t \tag{A.12}$$

- Good Market Clearing

$$y_t = c^{\star}_{H,t} + c_{H,t} + i_t \tag{A.13}$$

- Net Exports

$$nx_t = c^{\star}_{H,t} - p_{F,t} c_{F,t} \tag{A.14}$$

- Current Account

$$ca_t = -r_{t-1} p_t \frac{d_t}{e_t} + c^{\star}_{H,t} - p_{F,t} c_{F,t} \tag{A.15}$$

- Change in NFA

$$\Delta nfa_t = -g_t p_t \frac{d_{t+1}}{e_t} + p_{t-1} \frac{d_t}{e_{t-1}} \tag{A.16}$$

- Valuation Effects

$$val_t = d_t \left(\frac{p_{t-1}}{e_{t-1}} - \frac{p_t}{e_t} \right) = \Delta nfa_t - ca_t \tag{A.17}$$

- Transitory Technology Process

$$z_{t+1} = z_t^{\rho_z} \exp(\epsilon^z_{t+1}) \tag{A.18}$$

- Permanent Technology Process

$$g_{t+1} = \mu_g^{1-\rho_g} g_t^{\rho_g} \exp(\epsilon^g_{t+1}) \tag{A.19}$$

- Foreign Consumption Process

$$c^{\star}_{t+1} = (c^{\star}_t)^{\rho_c} \exp(\epsilon^c_{t+1}) \tag{A.20}$$

Moreover, note that

$$\frac{\partial u(c_t, 1-l_t)}{\partial c_t} = \frac{\gamma(c_t^\gamma(1-l_t)^{1-\gamma})^{1-\sigma}}{c_t}$$
$$\frac{\partial u(c_t, 1-l_t)}{\partial l_t} = -\frac{(1-\gamma)(c_t^\gamma(1-l_t)^{1-\gamma})^{1-\sigma}}{(1-l_t)}$$
$$\frac{\partial y_t}{\partial k_t} = \alpha\frac{y_t}{k_t}$$
$$\frac{\partial y_t}{\partial l_t} = (1-\alpha)\frac{y_t}{l_t}$$

Steady States

We now turn to the derivation of the deterministic steady state.

- From (A.18), $z = 1$.
- From (A.19), $g = \mu_g$.
- From (A.20), $c^\star = 1$.
- From (A.6), $r = \mu_g^{1-\gamma(1-\sigma)}\frac{1}{\beta} - 1$.
- From (A.4) and (A.6):

$$\mu_g^{\gamma(1-\delta)-1}\beta\left(\alpha\frac{y}{k} + 1 - \delta\right) = \mu_g^{\gamma(1-\delta)-1}\beta(1+r)$$
$$\alpha\frac{y}{k} + 1 - \delta = 1 + r$$
$$\frac{k}{y} = \frac{\alpha}{r+\delta}.$$

- From (A.3)

$$i = \left(\mu_g - 1 + \delta\right)k. \tag{*}$$

- From (A.2) using (*)

$$y = pc + i + (1 + r - \mu_g)\frac{pd}{e}$$
$$y = pc + \left(\mu_g - 1 + \delta\right)k + (1 + r - \mu_g)\frac{pd}{e}$$
$$\frac{pc}{y} = 1 + \left(1 - \delta - \mu_g\right)\frac{k}{y} + (\mu_g - 1 - r)\frac{pd}{ey}.$$

- From (A.5)

$$\frac{1-\gamma}{\gamma}\frac{pc}{1-l} = (1-\alpha)\frac{y}{l}$$
$$\frac{pc}{y} = (1-\alpha)\frac{\gamma}{1-\gamma}\frac{1-l}{l}$$
$$l = (1-\alpha)\frac{\gamma}{1-\gamma}\left(\frac{pc}{y} + (1-\alpha)\frac{\gamma}{1-\gamma}\right)^{-1}$$

or, equivalently

$$\gamma = \frac{pc}{y}\left((1-\alpha)\frac{1-l}{l} + \frac{pc}{y}\right)^{-1}.$$

- From (A.1)

$$y = zk^{\alpha}\left(\mu_g l\right)^{1-\alpha}$$
$$\frac{y}{k} = zk^{\alpha-1}\left(\mu_g l\right)^{1-\alpha}$$
$$k = \left(\frac{k}{y}\right)^{\frac{1}{1-\alpha}} \mu_g l z^{\frac{1}{1-\alpha}}.$$

- Accordingly, we get $y = \frac{y}{k}k$, $\frac{pd}{e} = \frac{pd}{ey}y$, and $pc = \frac{pc}{y}y$.

- From (*), we can determine i.

- From (A.16)

$$\Delta nfa = \frac{pd}{e}\left(1-\mu_g\right).$$

- From (A.17)

$$val = 0.$$

- From (A.15)

$$ca = \Delta nfa.$$

- From (A.14) and (A.15)

$$nx = ca + r\frac{pd}{e}.$$

- From (A.9) and (A.10), we can determine

$$p_F c_F = \left[\theta p_F^{\eta-1} + (1-\theta)\right]^{-1} (1-\theta) pc.$$

Then we can insert this expression together with (A.12) in equation (A.14) to derive a function of p_F:

$$(1-\theta)(nx + pc) = \left[\theta\theta^\star c^\star p_F^{\eta^\star} + (1-\theta)\theta^\star c^\star p_F^{\eta^\star-\eta-1} - \theta nx\right] p_F^{\eta-1}.$$

Unless $\eta = \eta^\star = 1$, this function cannot be solved for p_F analytically with pencil and paper. However, we can apply numerical methods to obtain p_F.

- From (A.10)

$$p = \left[\theta + (1-\theta) p_F^{1-\eta}\right]^{\frac{1}{1-\eta}}$$

- Then we can determine c as $c = \frac{pc}{p}$.
- From (A.12)

$$c_H^\star = \theta^\star p_F^{\eta^\star} c^\star$$

- From (A.8)

$$c_H = \theta p^\eta c$$

- From (A.9)

$$c_F = (1-\theta)\left(\frac{p}{p_F}\right)^\eta c$$

- From (A.11)

$$e = \frac{p}{p_F}$$

- Finally we have $d = \frac{pd}{e}\frac{e}{p}$.

A.2 Solving the Model

Finally, we end up with a stationary system of 20 non–linear difference equations (A.1)–(A.20) in 20 variables. The model features 3 exogenous state variables, 2 endogenous state variables and 15 control variables:

- Vector of exogenous state variables:
  $\mathbf{x}_{x,t} = \left[z_t \;\; g_t \;\; c_t^\star\right]'$
- Vector of endogenous state variables:
  $\mathbf{x}_{e,t} = [k_t \;\; d_t]'$
- Vector of control variables:
  $\mathbf{x}_{c,t} = \left[y_t \;\; c_t \;\; r_t \;\; e_t \;\; i_t \;\; l_t \;\; c_{H,t} \;\; c_{F,t} \;\; c_{H,t}^\star \;\; p_t \;\; p_{F,t} \;\; nx_t \;\; ca_t \;\; \Delta nfa_t \;\; val_t\right]'$.

Unfortunately, the model does not have a closed form solution. Therefore, we have to approximate its solution. We use a first–order approximation of the model solution.

First, we log–linearize the system around its deterministic steady state. To illustrate the straightforward concept of log–linearization, it is convenient to consider a system of only two variables z and y. We can write the system as an implicit function

$$f(z, y) = 0,$$

where z and y denote steady state values. Next, let us take the total differential to get

$$\begin{aligned} & \frac{\partial f(z,y)}{\partial z}\mathrm{d}z_t + \frac{\partial f(z,y)}{\partial y}\mathrm{d}y_t = 0 \\ \Leftrightarrow \quad & \frac{\partial f(z,y)}{\partial z}z\frac{\mathrm{d}z_t}{z} + \frac{\partial f(z,y)}{\partial y}y\frac{\mathrm{d}y_t}{y} = 0. \end{aligned}$$

Let $\widehat{z_t}$ denote log–deviations from the steady state. That is,

$$\widehat{z_t} \equiv \log\left(\frac{z_t}{z}\right) \approx \frac{z_t - z}{z} = \frac{\mathrm{d}z_t}{z}.$$

Consequently, our total differential from above can be rewritten as

$$0 = \frac{\partial f(z,y)}{\partial z}z\frac{\mathrm{d}z_t}{z} + \frac{\partial f(z,y)}{\partial y}y\frac{\mathrm{d}y_t}{y} \approx \left(\frac{\partial f(z,y)}{\partial z}z\right)\widehat{z_t} + \left(\frac{\partial f(z,y)}{\partial y}y\right)\widehat{y_t}.$$

Applying this method to the optimality and necessary conditions in the model at hand yields:

- Production Function

$$\widehat{y_t} = \widehat{z_t} + \alpha\widehat{k_t} + (1-\alpha)\widehat{g_t} + (1-\alpha)\widehat{l_t}$$

- Period t Resource Constraint

$$\begin{aligned}\widehat{y_t} = \frac{pc}{y}(\widehat{p_t} + \widehat{c_t}) + \frac{i}{y}\widehat{i_t} + \frac{pd}{ey}(1+r)\left(\widehat{d_t} + \widehat{p_t} - \widehat{e_t}\right) \\ + \frac{pd}{ey}r\widehat{r_{t-1}} + \frac{pd}{ey}\mu_g\left(\widehat{g_t} + \mathrm{E}_t\left[\widehat{d_{t+1}}\right] + \widehat{p_t} - \widehat{e_t}\right)\end{aligned}$$

- Law of Motion of Capital

$$\widehat{g_t} + \mathrm{E}_t\left[\widehat{k_{t+1}}\right] = \frac{1-\delta}{\mu_g}\widehat{k_t} + \frac{i}{\mu_g k}\widehat{i_t}$$

- Investment Euler Equation

$$\begin{aligned}(\gamma(1-\sigma)-1)\widehat{c_t} - (1-\gamma)(1-\sigma)\widehat{l_t} + \phi\mu_g\Big(\widehat{g_t} + \mathrm{E}_t[\widehat{k_{t+1}}] - \widehat{k_t}\Big) = \mu_g^{\gamma(1-\sigma)-1}\beta\cdot \\ \Big[\Big(\alpha\frac{y}{k} + 1 - \delta\Big)\Big((\gamma(1-\sigma)-1)\widehat{g_t} + \widehat{p_t} - \widehat{p_{t+1}} + (\gamma(1-\sigma)-1)\mathrm{E}_t[\widehat{c_{t+1}}] - \\ (1-\gamma)(1-\sigma)\mathrm{E}_t[\widehat{l_{t+1}}]\Big) + \alpha\frac{y}{k}\Big(\mathrm{E}_t[\widehat{y_{t+1}}] - \mathrm{E}_t[\widehat{k_{t+1}}]\Big) \\ + \mu_g^2\phi\Big(\mathrm{E}_t[\widehat{g_{t+1}}] + \mathrm{E}_t[\widehat{k_{t+2}}] - \mathrm{E}_t[\widehat{k_{t+1}}]\Big)\Big]\end{aligned}$$

- Labor–Leisure Trade–off

$$\widehat{y_t} = \widehat{p_t} + \widehat{c_t} + \frac{1}{1-l}\widehat{l_t}$$

- Bond Euler Equation

$$\begin{aligned}\beta\mu_g^{\gamma(1-\sigma)-1}(1+r)\left((\gamma(1-\sigma)-1)\widehat{g_t} + \widehat{e_t} - \mathrm{E}_t[\widehat{e_{t+1}}] + \frac{r}{1+r}\widehat{r_t}\right) \\ = (1-(1-\sigma)\gamma)\left(\mathrm{E}_t[\widehat{c_{t+1}}] - \widehat{c_t}\right) + \frac{l}{1-l}\left(\frac{1}{1-l}\mathrm{E}_t[\widehat{l_{t+1}}] - \widehat{l_t}\right)\end{aligned}$$

- Interest Rate

$$\widehat{r_t} = \frac{\psi}{r}\frac{pd}{ey}\left[\mathrm{E}_t[\widehat{d_{t+1}}] + \mathrm{E}_t[\widehat{p_{t+1}}] - \mathrm{E}_t[\widehat{y_{t+1}}] - \mathrm{E}_t[\widehat{e_{t+1}}]\right]$$

- Consumption of the Home Good

$$\widehat{c_{H,t}} = \eta\widehat{p_t} + \widehat{c_t}$$

- Consumption of the Foreign Good

$$\widehat{c_{F,t}} = \eta\left(\widehat{p_t} - \widehat{p_{F,t}}\right) + \widehat{c_t}$$

- Price of Consumption

$$\widehat{p_t} = \frac{(1-\theta)p_F^{1-\eta}}{\theta + (1-\theta)p_F^{1-\eta}}\widehat{p_{F,t}}$$

- Exchange Rate

$$\widehat{e_t} = \widehat{p_t} - \widehat{p_{F,t}}$$

- Exports of Home Goods

$$\widehat{c^{\star}_{H,t}} = \eta^{\star}\widehat{p_{F,t}} + \widehat{c^{\star}_t}$$

- Good Market Clearing

$$\widehat{y_t} = \frac{c^{\star}_H}{y}\widehat{c^{\star}_{H,t}} + \frac{c_H}{y}\widehat{c_{H,t}} + \frac{i}{y}\widehat{i_t}$$

- Net Exports

$$\widehat{nx_t} = \frac{c^{\star}_H}{nx}\widehat{c^{\star}_{H,t}} - \frac{p_F c_F}{nx}\left(\widehat{p_{F,t}} + \widehat{c_{F,t}}\right)$$

- Current Account

$$\widehat{ca_t} = \frac{c^{\star}_H}{ca}\widehat{c^{\star}_{H,t}} - \frac{p_F c_F}{y}\widehat{p_{F,t}} - \frac{p_F c_F}{y}\widehat{c_{F,t}} - \frac{r}{ca}\frac{pd}{e}\left(\widehat{r_{t-1}} + \widehat{p_t} + \widehat{d_t} - \widehat{e_t}\right)$$

- Change in NFA

$$
\begin{aligned}
\Delta nfa\widehat{\Delta nfa_t} =& -\mu_g\frac{dp}{e}\left[\widehat{g_t} + \mathrm{E}_t[\widehat{d_{t+1}}] + \widehat{p_t} - \widehat{e_t}\right] \\
& \frac{dp}{e}\left[\widehat{d_t} + \widehat{p_{t-1}} - \widehat{e_{t-1}}\right] \\
\Leftrightarrow \qquad \widehat{\Delta nfa_t} =& \frac{1}{\mu_g - 1}\left[\mu_g\widehat{g_t} + \mu_g\mathrm{E}_t[\widehat{d_{t+1}}] - \widehat{d_t} + \mu_g\widehat{p_t} - \widehat{p_{t-1}} - \mu_g\widehat{e_t} + \widehat{e_{t-1}}\right]
\end{aligned}
$$

- Valuation Effects

  Valuation effects are zero in steady state. Therefore, we cannot determine its log–deviation from steady state. Absolute deviation from steady state is given by

$$
\Delta val_t = \Delta\left(\Delta nfa_t\right) - \Delta ca_t
$$

- Transitory Technology Process

$$
\widehat{z_t} = \rho_z\widehat{z_{t-1}} + \epsilon_t^z
$$

- Permanent Technology Process

$$
\widehat{g_t} = \rho_g\widehat{g_{t-1}} + \epsilon_t^g
$$

- Foreign Consumption Process

$$
\widehat{c_t^\star} = \rho_c\widehat{c_{t-1}^\star} + \epsilon_t^c
$$

These conditions constitute a linear system of (expectational) difference equations of the form

$$
\widetilde{\mathbf{A}}\,\mathrm{E}_t\left[\widehat{\mathbf{x}}_{t+1}\right] = \widetilde{\mathbf{B}}\,\widehat{\mathbf{x}}_t,
$$

where

$$
\mathrm{E}_t\left[\widehat{\mathbf{x}}_{t+1}\right] = \begin{pmatrix} \mathrm{E}_t\left[\widehat{\mathbf{x}}_{e,t+1}\right] \\ \mathrm{E}_t\left[\widehat{\mathbf{x}}_{x,t+1}\right] \\ \mathrm{E}_t\left[\widehat{\mathbf{x}}_{c,t+1}\right] \end{pmatrix} = \begin{pmatrix} \mathrm{E}_t\left[\widehat{\mathbf{x}}_{s,t+1}\right] \\ \mathrm{E}_t\left[\widehat{\mathbf{x}}_{c,t+1}\right] \end{pmatrix},
$$

and $\widehat{\mathbf{x}}_{s,t+1} \equiv [\widehat{\mathbf{x}}_{e,t+1} \quad \widehat{\mathbf{x}}_{x,t+1}]'$ denotes the vector of state variables in log–deviations from steady state.

Second, we use the methodology suggested by Klein (2000) to solve the log–linear approximation of the model. This approach allows to express the model in state space form:

- *Measurement Equation*

$$\widehat{\mathbf{x}}_{c,t} = \mathbf{Z}\,\widehat{\mathbf{x}}_{s,t}$$

- *Transition Equation*

$$\widehat{\mathbf{x}}_{s,t} = \mathbf{T}\,\widehat{\mathbf{x}}_{s,t-1} + \mathbf{R}\boldsymbol{\epsilon}_t, \qquad \boldsymbol{\epsilon}_t \sim \mathcal{N}(\mathbf{0}, \boldsymbol{\Sigma})$$

with

$$\mathbf{R} = \begin{pmatrix} 0 & 0 & 0 \\ 0 & 0 & 0 \\ 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{pmatrix}$$

$$\boldsymbol{\epsilon}_t = \begin{pmatrix} \epsilon_t^z \\ \epsilon_t^g \\ \epsilon_t^c \end{pmatrix}$$

$$\boldsymbol{\Sigma} = \begin{pmatrix} \sigma_z^2 & 0 & 0 \\ 0 & \sigma_g^2 & 0 \\ 0 & 0 & \sigma_c^2 \end{pmatrix}.$$

A.3 Estimation Results

A.3.1 Data for Estimation

Our estimation exercise relies on quarterly data of real per capita output and consumption as well as real interest rates and real exchange rates. The data section in the main text describes how we construct these real time series. Figures

A.1 to A.12 plot the series of our four variables in logs and the associated cubic trends for each country under investigation. The second row in each graph shows the cycle of the corresponding variable calculated by the log deviation from the cubic trend. Regarding real interest rates, the figures display the logarithm of the gross real interest rate.

Figure A.1: Output and Consumption – Mexico

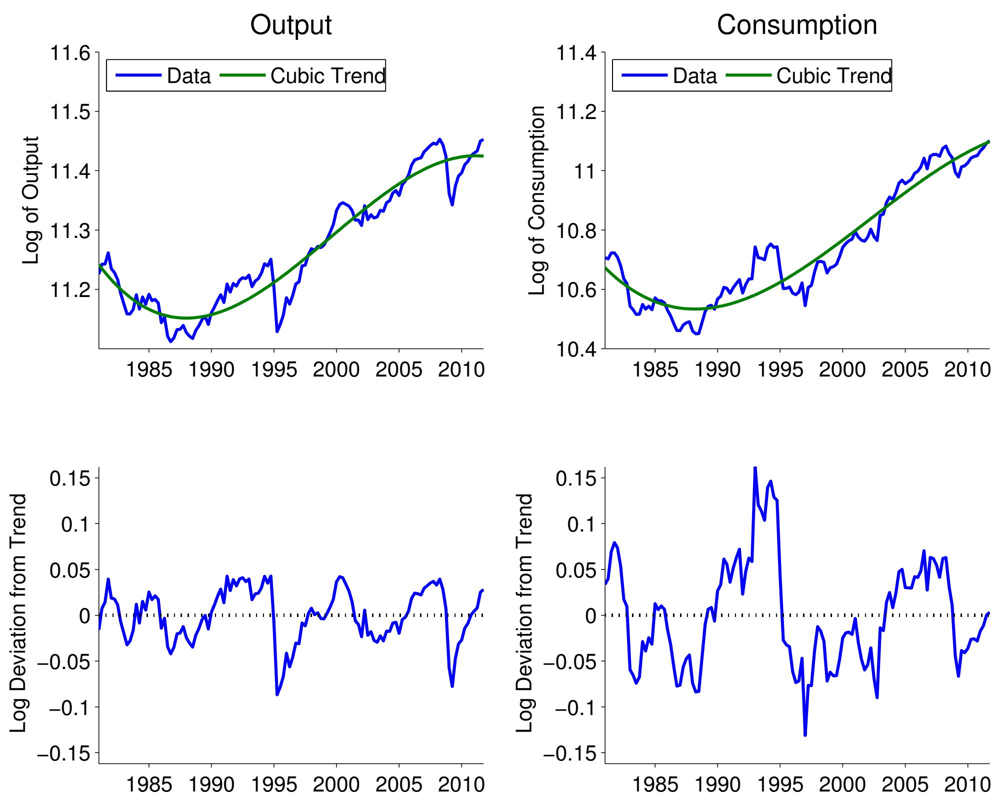


Figure A.2: Interest and Exchange Rates – Mexico

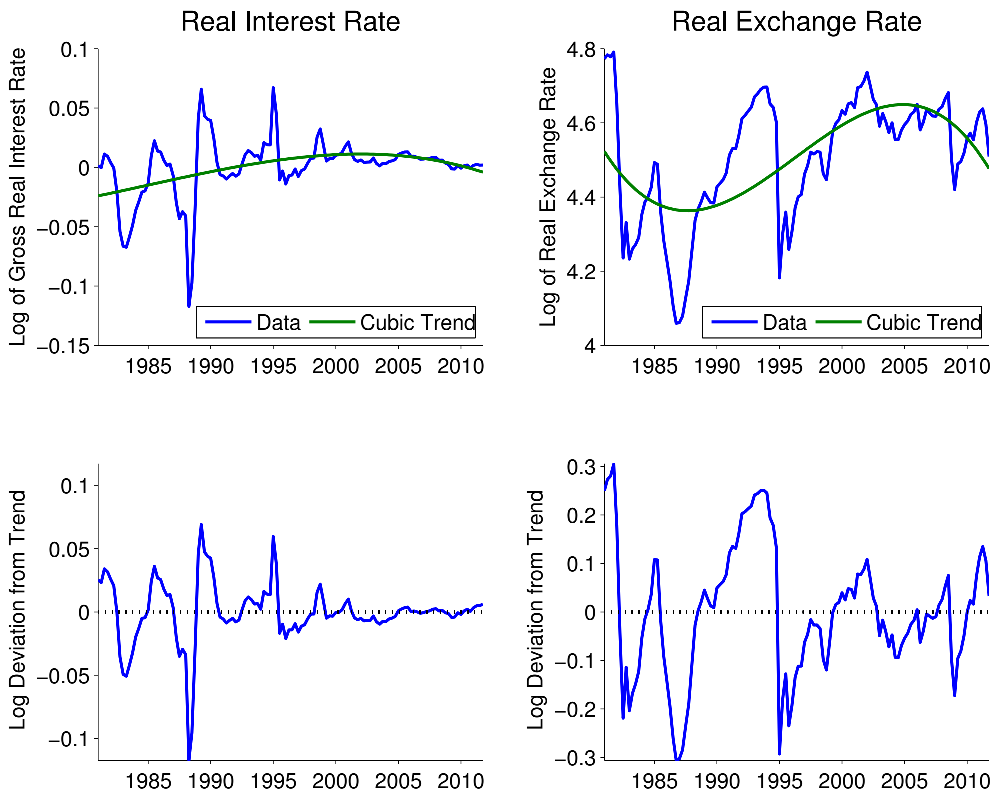


Figure A.3: Output and Consumption – South Africa

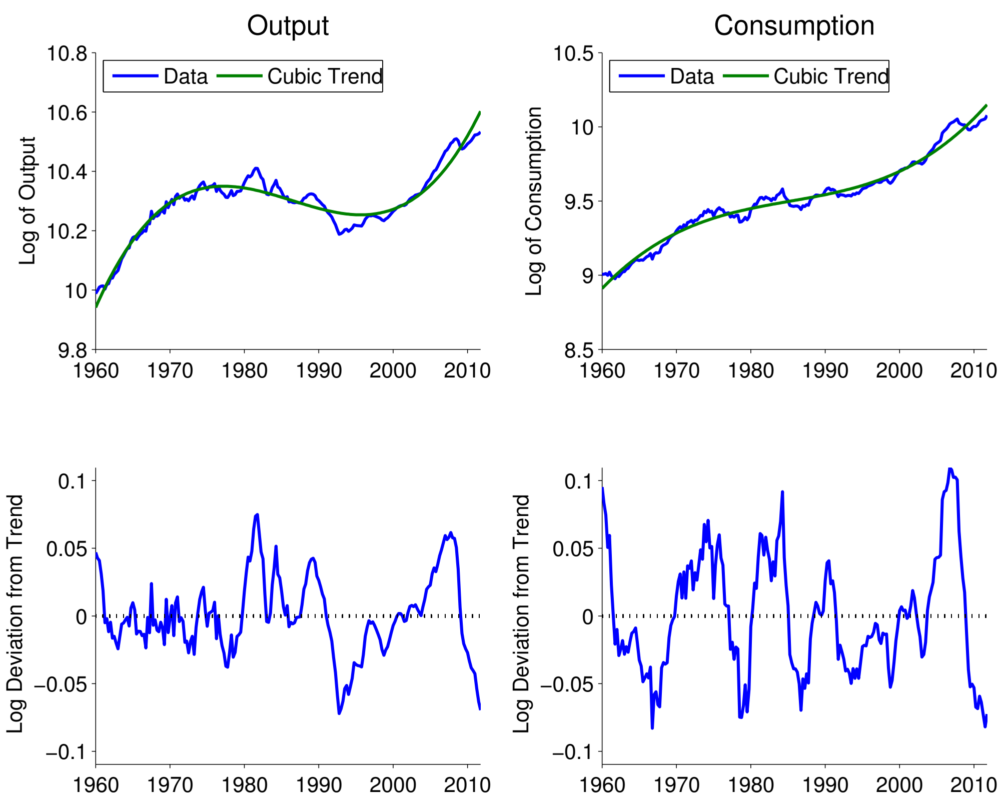


Figure A.4: Interest and Exchange Rates – South Africa

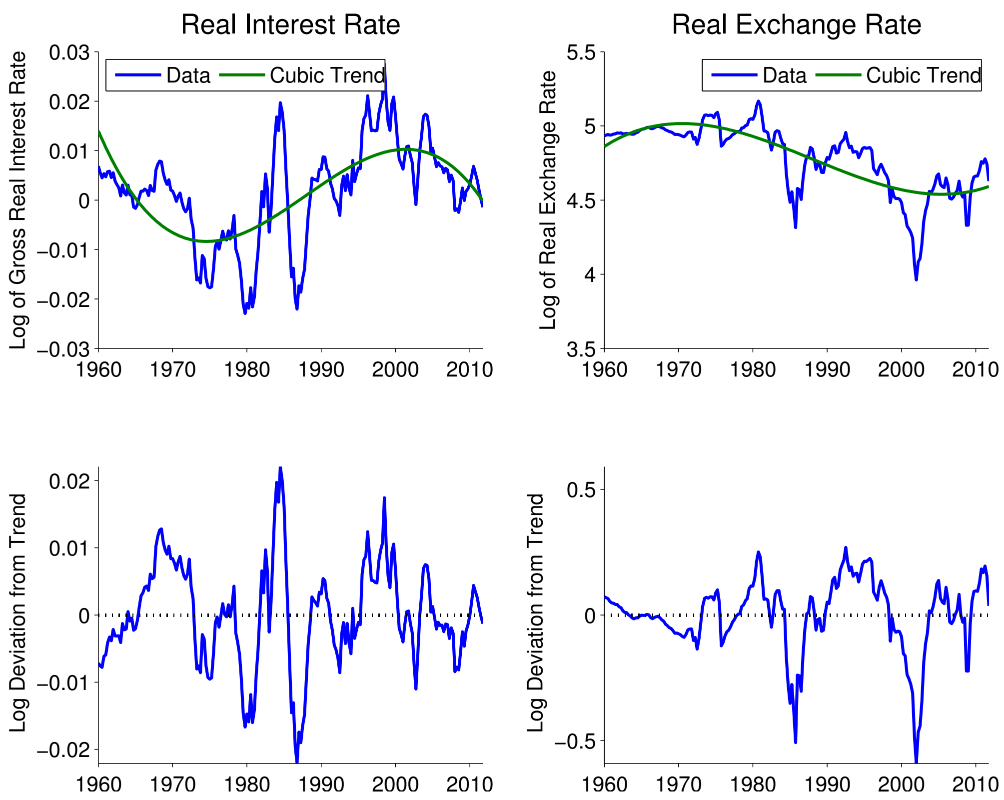


Figure A.5: Output and Consumption – Turkey

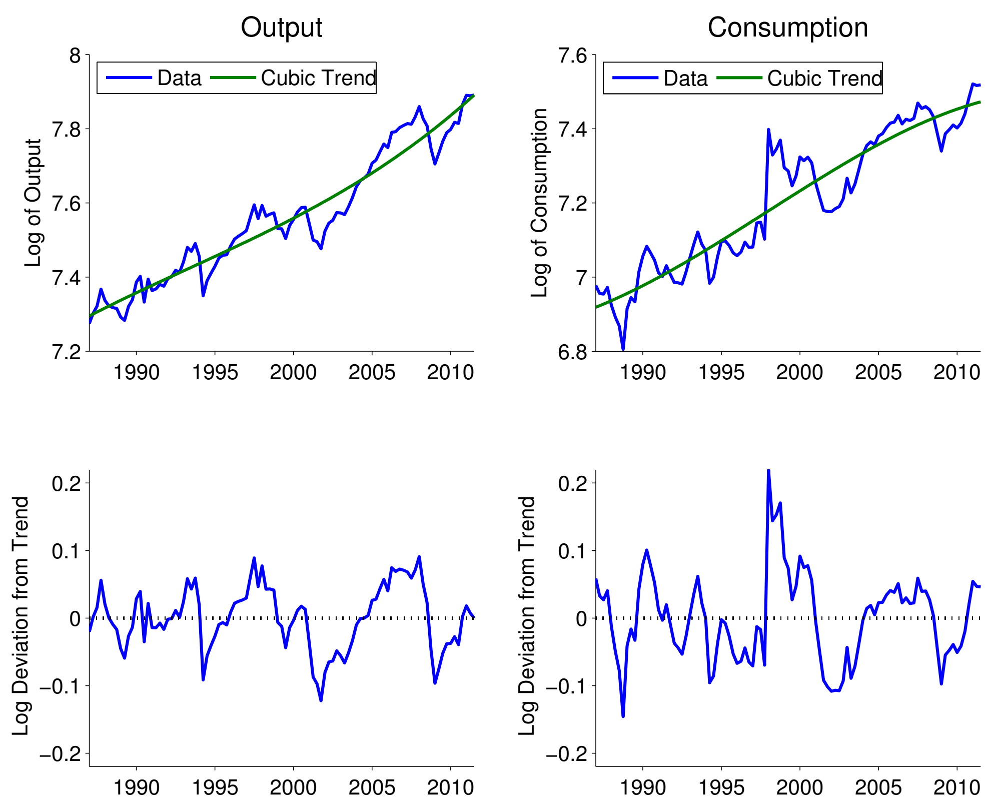


Figure A.6: Interest and Exchange Rates – Turkey

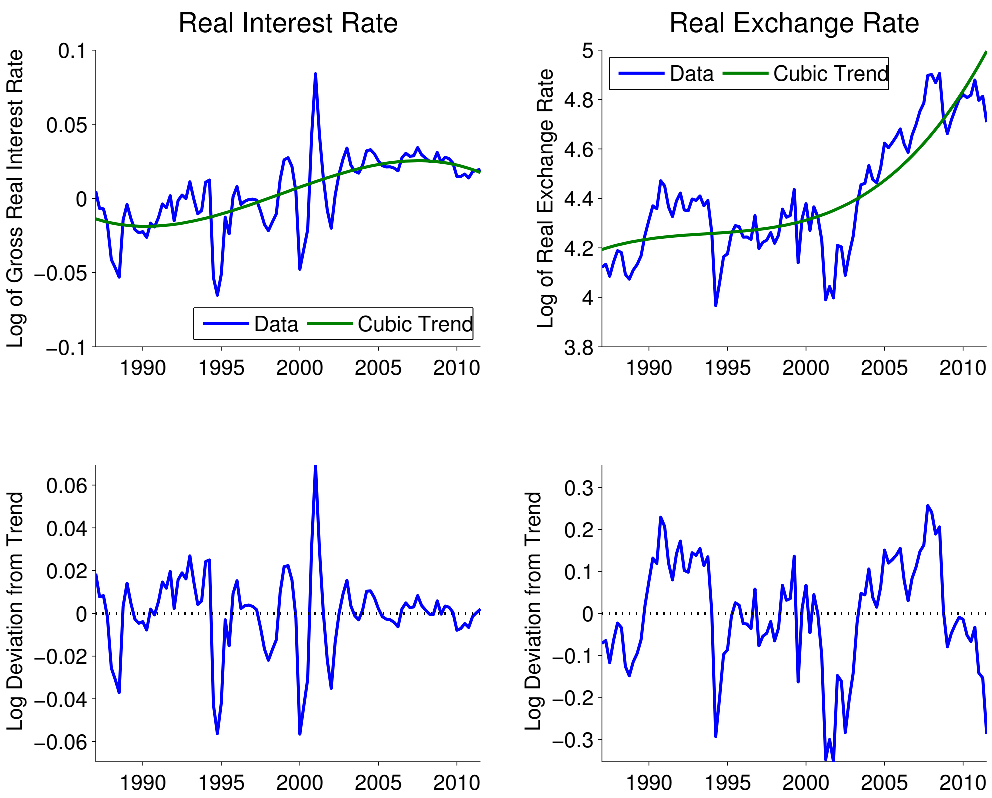


Figure A.7: Output and Consumption – Canada

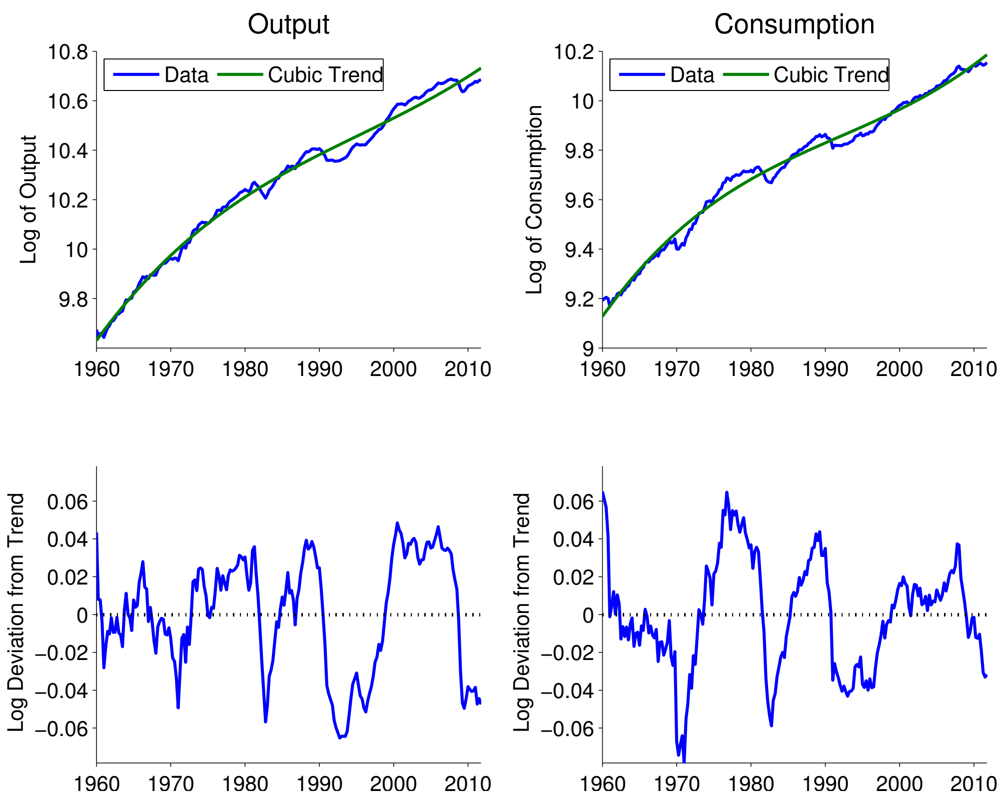


Figure A.8: Interest and Exchange Rates – Canada

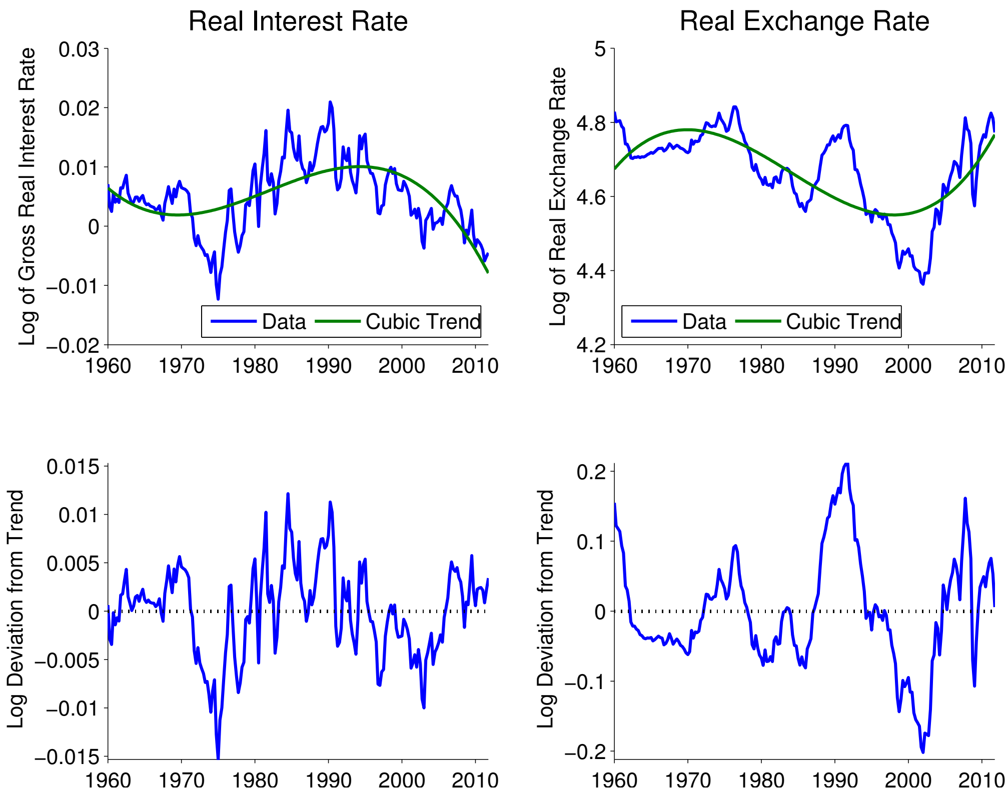


Figure A.9: Output and Consumption – Sweden

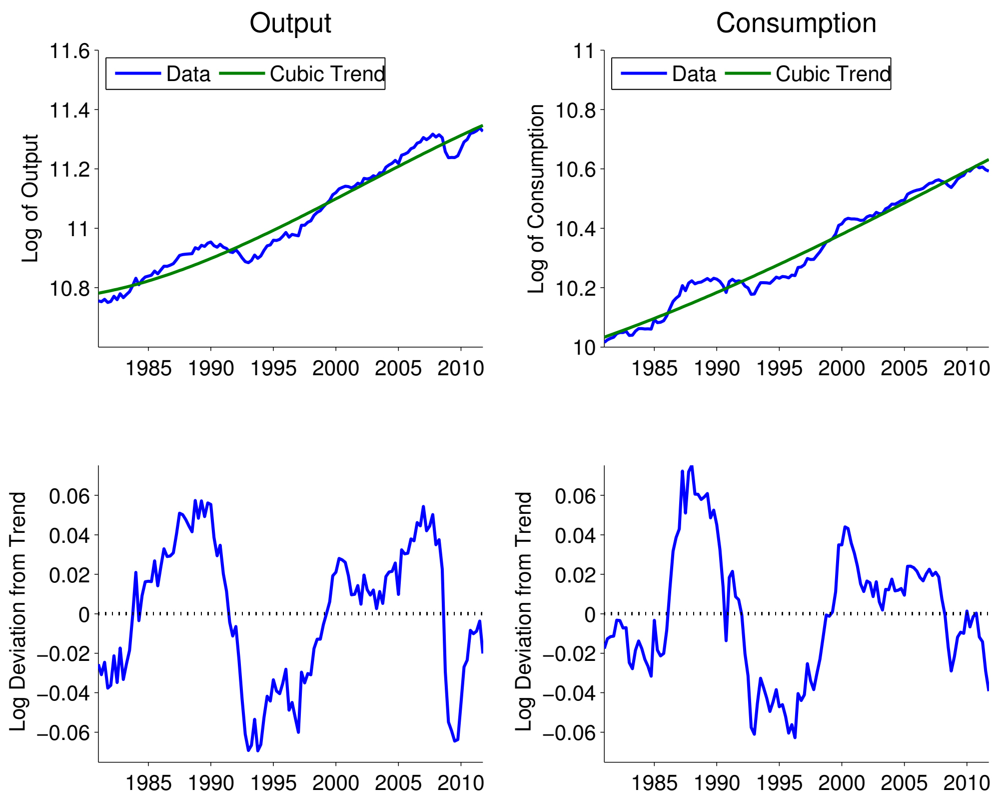


Figure A.10: Interest and Exchange Rates – Sweden

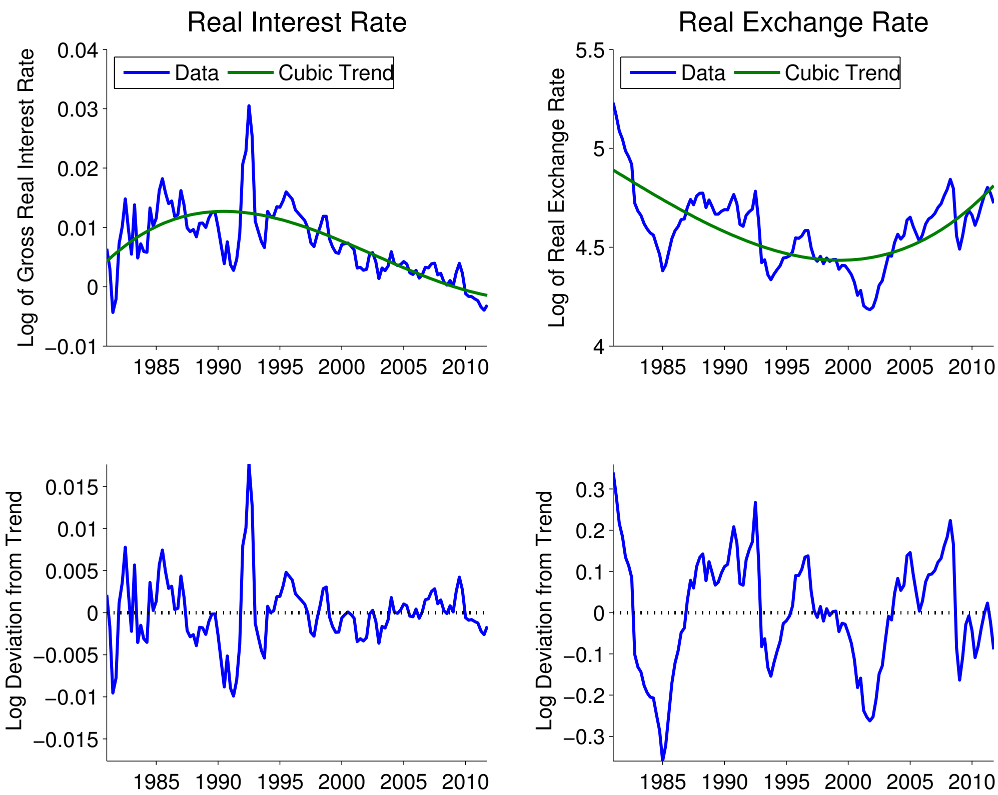


Figure A.11: Output and Consumption – Switzerland

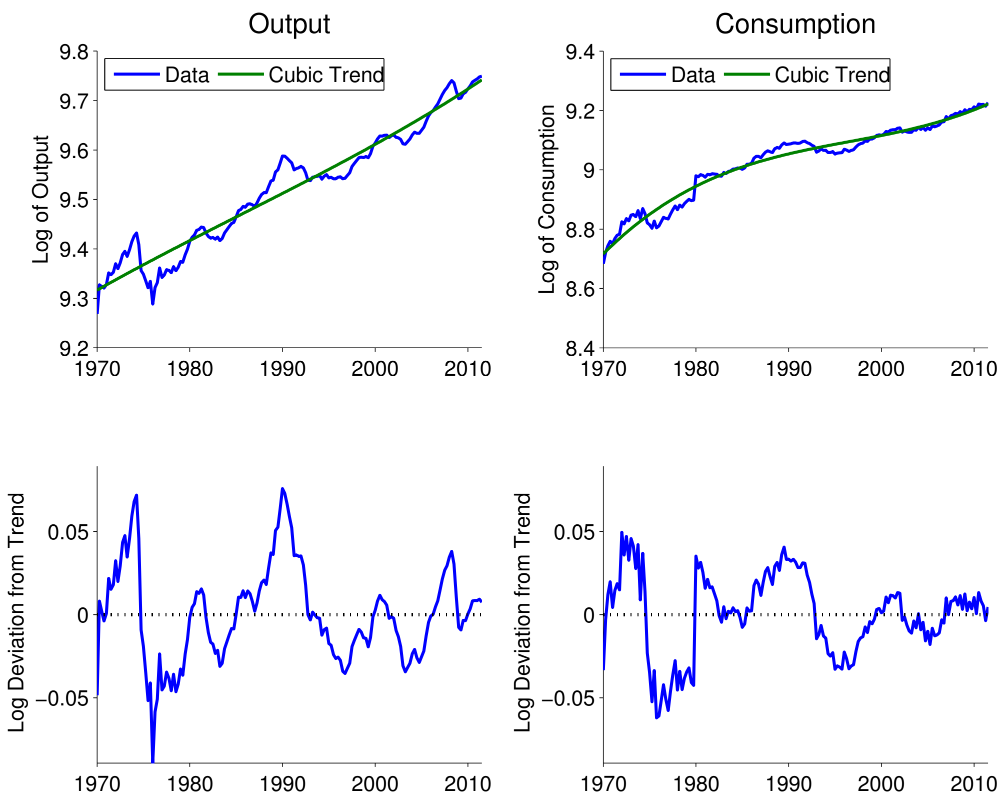
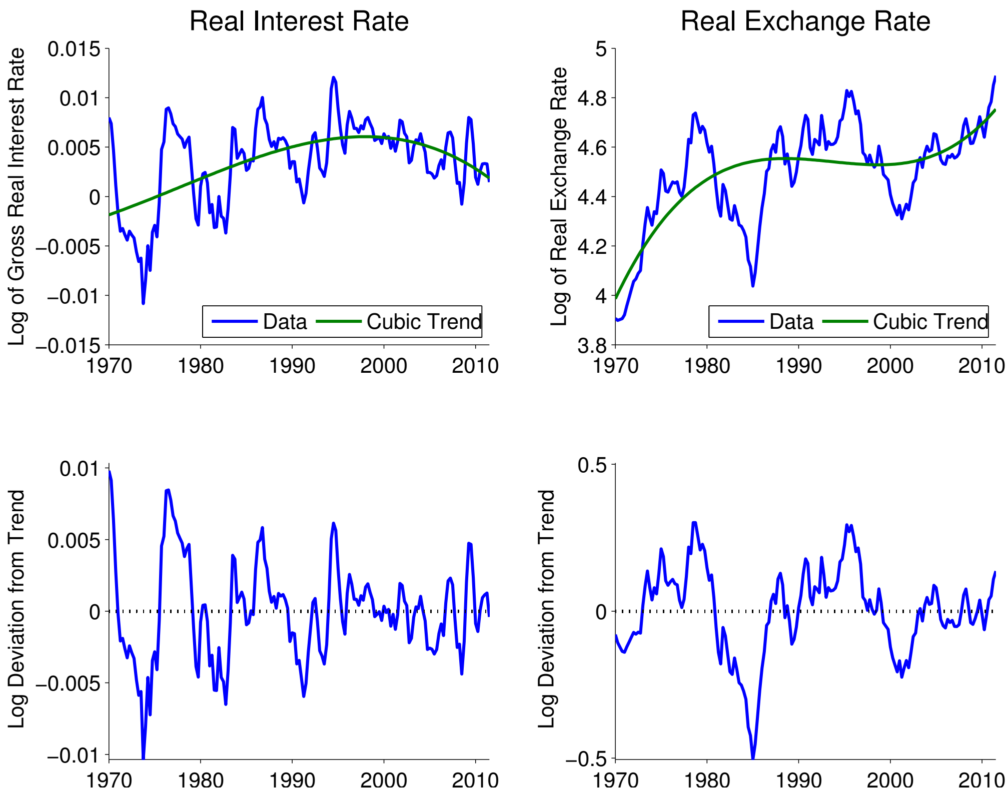


Figure A.12: Interest and Exchange Rates – Switzerland



A.3.2 Parameter Distributions

Table A.1 complements Table 5 in the main text and presents a detailed summary of the posterior distributions of our estimated parameters including those determining the off–model dynamics.

Table A.1: Prior & Posterior Distributions – Emerging Market Economies

	Post. Median	Post. 90%	χ^2 Test	Post. Median	Post. 90%	χ^2 Test	Post. Median	Post. 90%	χ^2 Test	Post. Median	Post. 90%	χ^2 Test	Post. Median	Post. 90%	χ^2 Test	Post. Median	Post. 90%	χ^2 Test
	Mexico						**South Africa**						**Turkey**					
	Benchmark			**Liability Dollar.**			**Benchmark**			**Liability Dollar.**			**Benchmark**			**Liability Dollar.**		
ψ	4.342	[3.315,4.885]	0.27	0.216	[0.088,0.488]	0.96	1.664	[1.115,2.668]	0.31	0.275	[0.158,0.420]	0.93	4.067	[2.743,4.830]	0.50	0.455	[0.126,1.182]	0.86
ρ_z	0.622	[0.487,0.744]	0.58	0.708	[0.574,0.828]	0.50	0.918	[0.874,0.958]	0.50	0.782	[0.679,0.863]	0.92	0.691	[0.552,0.803]	0.25	0.648	[0.512,0.763]	0.24
ρ_g	0.751	[0.637,0.845]	0.58	0.790	[0.632,0.890]	0.26	0.827	[0.767,0.886]	0.86	0.797	[0.690,0.869]	0.95	0.629	[0.508,0.741]	0.46	0.705	[0.561,0.811]	0.10
ρ_c	0.689	[0.458,0.875]	0.37	0.547	[0.365,0.726]	0.21	0.626	[0.442,0.815]	0.43	0.654	[0.466,0.798]	0.59	0.646	[0.428,0.822]	0.49	0.507	[0.338,0.655]	0.48
ρ_{ϵ_y}	0.251	[-0.007,0.510]	0.59	0.221	[-0.037,0.504]	0.98	0.233	[0.010,0.489]	0.94	0.282	[0.041,0.551]	0.35	0.345	[0.030,0.730]	0.48	0.230	[-0.050,0.568]	0.91
ρ_{ϵ_c}	0.876	[0.782,0.936]	0.74	0.743	[0.204,0.897]	0.65	0.925	[0.890,0.958]	0.82	0.908	[0.859,0.949]	0.36	0.620	[0.447,0.745]	0.31	0.371	[0.029,0.653]	0.37
ρ_{ϵ_r}	0.708	[0.625,0.787]	0.27	0.747	[0.676,0.820]	0.57	0.434	[0.186,0.686]	0.68	0.802	[0.548,0.888]	0.93	0.503	[0.364,0.626]	0.23	0.512	[0.384,0.626]	0.76
ρ_{ϵ_e}	0.836	[0.760,0.897]	0.58	0.837	[0.772,0.897]	0.62	0.913	[0.876,0.948]	0.80	0.904	[0.865,0.943]	0.15	0.728	[0.521,0.828]	0.08	0.778	[0.685,0.861]	0.63
σ^2_z	0.034	[0.028,0.043]	0.91	0.036	[0.029,0.044]	0.79	0.015	[0.014,0.018]	0.85	0.020	[0.017,0.023]	0.91	0.062	[0.049,0.078]	0.87	0.059	[0.045,0.075]	0.49
σ^2_g	0.040	[0.031,0.052]	0.26	0.029	[0.021,0.039]	0.83	0.012	[0.010,0.014]	0.22	0.016	[0.012,0.021]	0.86	0.080	[0.060,0.107]	0.14	0.074	[0.053,0.101]	0.66
σ^2_c	0.128	[0.082,0.201]	0.89	0.189	[0.106,0.370]	0.45	0.082	[0.059,0.110]	0.34	0.086	[0.058,0.137]	0.56	0.201	[0.114,0.384]	0.12	0.192	[0.103,0.428]	0.20
$\sigma^2_{\epsilon_y}$	0.006	[0.004,0.008]	0.26	0.006	[0.005,0.009]	0.32	0.004	[0.003,0.005]	0.33	0.004	[0.003,0.005]	0.55	0.023	[0.015,0.037]	0.83	0.022	[0.015,0.036]	0.36
$\sigma^2_{\epsilon_c}$	0.024	[0.019,0.031]	0.74	0.027	[0.019,0.038]	0.15	0.017	[0.014,0.021]	0.49	0.014	[0.011,0.018]	0.77	0.092	[0.069,0.119]	0.75	0.059	[0.038,0.088]	0.21
$\sigma^2_{\epsilon_r}$	0.021	[0.018,0.025]	0.60	0.023	[0.020,0.027]	0.95	0.000	[0.000,0.001]	0.17	0.001	[0.000,0.001]	0.66	0.015	[0.011,0.019]	0.63	0.020	[0.015,0.024]	0.89
$\sigma^2_{\epsilon_e}$	0.320	[0.260,0.387]	0.81	0.330	[0.269,0.399]	0.12	0.284	[0.251,0.320]	0.06	0.272	[0.238,0.307]	0.19	0.560	[0.411,0.689]	0.33	0.671	[0.549,0.816]	0.68
	Canada						**Sweden**						**Switzerland**					
	Benchmark						**Benchmark**						**Benchmark**					
ψ	2.335	[1.646,3.573]	0.14				2.490	[1.486,4.103]	0.89				0.165	[0.141,0.193]	0.54			
ρ_z	0.901	[0.852,0.948]	0.38				0.885	[0.829,0.939]	0.95				0.880	[0.826,0.931]	0.55			
ρ_g	0.757	[0.676,0.832]	0.91				0.597	[0.488,0.706]	0.15				0.596	[0.486,0.699]	0.52			
ρ_c	0.920	[0.860,0.958]	0.53				0.738	[0.523,0.878]	0.53				0.697	[0.515,0.835]	0.92			
ρ_{ϵ_y}	0.704	[0.474,0.875]	0.47				0.411	[0.139,0.679]	0.37				0.354	[0.118,0.610]	0.43			
ρ_{ϵ_c}	0.827	[0.701,0.894]	0.75				0.773	[0.651,0.865]	0.20				0.830	[0.761,0.887]	0.57			
ρ_{ϵ_r}	0.465	[0.238,0.677]	0.76				0.275	[0.024,0.510]	0.71				0.303	[0.085,0.522]	0.87			
ρ_{ϵ_e}	0.913	[0.863,0.953]	0.46				0.878	[0.829,0.925]	0.95				0.931	[0.896,0.964]	0.58			
σ^2_z	0.013	[0.011,0.015]	0.70				0.022	[0.018,0.025]	0.46				0.014	[0.013,0.016]	0.48			
σ^2_g	0.009	[0.008,0.011]	0.56				0.018	[0.015,0.022]	0.80				0.012	[0.010,0.014]	0.89			
σ^2_c	0.047	[0.038,0.058]	0.88				0.074	[0.055,0.102]	0.55				0.093	[0.067,0.129]	0.25			
$\sigma^2_{\epsilon_y}$	0.004	[0.003,0.005]	0.15				0.007	[0.005,0.009]	0.09				0.004	[0.003,0.005]	0.70			
$\sigma^2_{\epsilon_c}$	0.005	[0.004,0.006]	0.76				0.011	[0.009,0.014]	0.83				0.008	[0.006,0.010]	0.92			
$\sigma^2_{\epsilon_r}$	0.000	[0.000,0.000]	0.48				0.000	[0.000,0.000]	0.62				0.000	[0.000,0.000]	0.37			
$\sigma^2_{\epsilon_e}$	0.040	[0.033,0.047]	0.74				0.285	[0.244,0.332]	0.85				0.239	[0.209,0.276]	0.33			

Notes: Results are based on 150,000 draws from the posterior distribution, of which for EMEs 100,000, and for developed economies the first 125,000 draws were burned. To avoid autocorrelation issues, we only keep every 10^{th} draw for developed economies, and every 25^{th} for EMEs. The χ^2 figure denotes the p–value of Geweke's χ^2–test for convergence (4 % taper). Variances are reported in percentages.

A.3.3 Random Walk Component of the Solow Residual

Aguiar and Gopinath (2007) assess the relative importance of trend shocks by calculating the random walk component (RWC) of the Solow residual. Recall that our production function is given by

$$Y_t = z_t K_t^{\alpha} (\Gamma_t l_t)^{1-\alpha}.$$

Hence, we can define Total Factor Productivity (TFP) as

$$TFP_t = z_t \Gamma_t^{1-\alpha},$$

such that our production function reads

$$Y_t = TFP_t K_t^{\alpha} l_t^{1-\alpha}.$$

Log output in first differences is then

$$\Delta \log(Y_t) = \Delta \log(TFP_t) + \alpha \Delta \log(K_t) + (1-\alpha) \Delta \log(l_t),$$

where

$$\begin{aligned}
& \Delta \log(TFP_t) = \Delta \log(z_t) + (1-\alpha) \Delta \log(\Gamma_t) \\
\Leftrightarrow \quad & \Delta \log(TFP_t) = \Delta \log(z_t) + (1-\alpha) \left(\log(g_t) + \log(\Gamma_{t-1}) - \log(\Gamma_{t-1})\right) \\
\Leftrightarrow \quad & \Delta \log(TFP_t) = \Delta \log(z_t) + (1-\alpha) \log(g_t)
\end{aligned}$$

is the famous Solow residual.

The variance of the Solow residual is given by the sum of the variance of $\Delta \log(z_t)$ and the variance of $(1-\alpha)\log(g_t)$. Let us first compute the variance of

$\log(g_t)$:

$$\begin{aligned}
& Var(\log(g_t)) = Var((1-\rho_g)\mu_g + \rho_g \log(g_{t-1}) + \epsilon_t^g) \\
\Leftrightarrow \qquad & Var(\log(g_t)) = \rho_g^2 Var(\log(g_{t-1})) + \sigma_g^2 \\
\Leftrightarrow \qquad & Var(\log(g_t)) = \frac{\sigma_g^2}{(1-\rho_g^2)},
\end{aligned}$$

where we use the fact that $\log(g_t)$ follows a stationary AR(1) process such that $Var(\log(g_t)) = Var(\log(g_{t-1}))$. Next, we calculate the variance of $\Delta\log(z_t)$:

$$\begin{aligned}
& Var(\Delta\log(z_t)) = Var(\log(z_t) - \log(z_{t-1})) \\
\Leftrightarrow \qquad & Var(\Delta\log(z_t)) = Var(\rho_z \log(z_{t-1}) + \epsilon_t^z - \log(z_{t-1})) \\
\Leftrightarrow \qquad & Var(\Delta\log(z_t)) = Var(-(1-\rho_z)\log(z_{t-1}) + \epsilon_t^z) \\
\Leftrightarrow \qquad & Var(\Delta\log(z_t)) = (1-\rho_z)^2 Var(\log(z_{t-1})) + \sigma_z^2 \\
\Leftrightarrow \qquad & Var(\Delta\log(z_t)) = (1-\rho_z)^2 \frac{\sigma_z^2}{(1-\rho_z^2)} + \sigma_z^2 \\
\Leftrightarrow \qquad & Var(\Delta\log(z_t)) = (1-\rho_z)^2 \frac{\sigma_z^2}{(1+\rho_z)(1-\rho_z)} + \sigma_z^2 \\
\Leftrightarrow \qquad & Var(\Delta\log(z_t)) = (1-\rho_z) \frac{\sigma_z^2}{(1+\rho_z)} + \sigma_z^2 \\
\Leftrightarrow \qquad & Var(\Delta\log(z_t)) = \left(\frac{1-\rho_z}{1+\rho_z} + 1\right)\sigma_z^2 \\
\Leftrightarrow \qquad & Var(\Delta\log(z_t)) = \frac{2}{1+\rho_z}\sigma_z^2,
\end{aligned}$$

where, again, we use the fact that $\log(z_t)$ follows a stationary AR(1) process such that $Var(\log(z_t)) = Var(\log(z_{t-1}))$. Accordingly, the variance of the Solow residual is given by

$$\begin{aligned}
& Var(\Delta\log(TFP_t)) = Var(\Delta\log(z_t)) + (1-\alpha)^2 Var(\log(g_t)) \\
\Leftrightarrow \qquad & Var(\Delta\log(TFP_t)) = \frac{2\sigma_z^2}{1+\rho_z} + \frac{(1-\alpha)^2\sigma_g^2}{(1-\rho_g^2)}.
\end{aligned}$$

The random walk component of the Solow residual is then the portion of the variance of $\Delta\log(TFP_t)$ that can be attributed to the non–stationary productivity component:

$$RWC = \frac{\frac{(1-\alpha)^2\sigma_g^2}{(1-\rho_g^2)}}{\frac{2\sigma_z^2}{1+\rho_z} + \frac{(1-\alpha)^2\sigma_g^2}{(1-\rho_g^2)}}.$$

Note that this equation is the counterpart of equation (14) in the paper by Aguiar and Gopinath (2007).

Table A.2 summarizes the random walk component of the Solow residual as well as the ratio of standard deviations $\frac{\sigma_g}{\sigma_z}$ computed at the median of the posterior distribution. For Mexico and Canada we also report the GMM estimates obtained by Aguiar and Gopinath (2007). Our calculations suggest that the random walk

Table A.2: Random Walk Component and Volatility Ratio

	Benchmark	Liability Dollarization	AG (2007)
	Random Walk Component		
Emerging Markets			
MEX	0.88	0.88	0.88
ZAF	0.92	0.89	
TUR	0.79	0.85	
Developed Economies			
CAN	0.84		0.40
SWE	0.69		
CHE	0.70		
	Ratio of Volatilities		
Emerging Markets			
MEX	1.09	0.90	4.02
ZAF	0.89	0.89	
TUR	1.14	1.12	
Developed Economies			
CAN	0.83		0.75
SWE	0.90		
CHE	0.93		

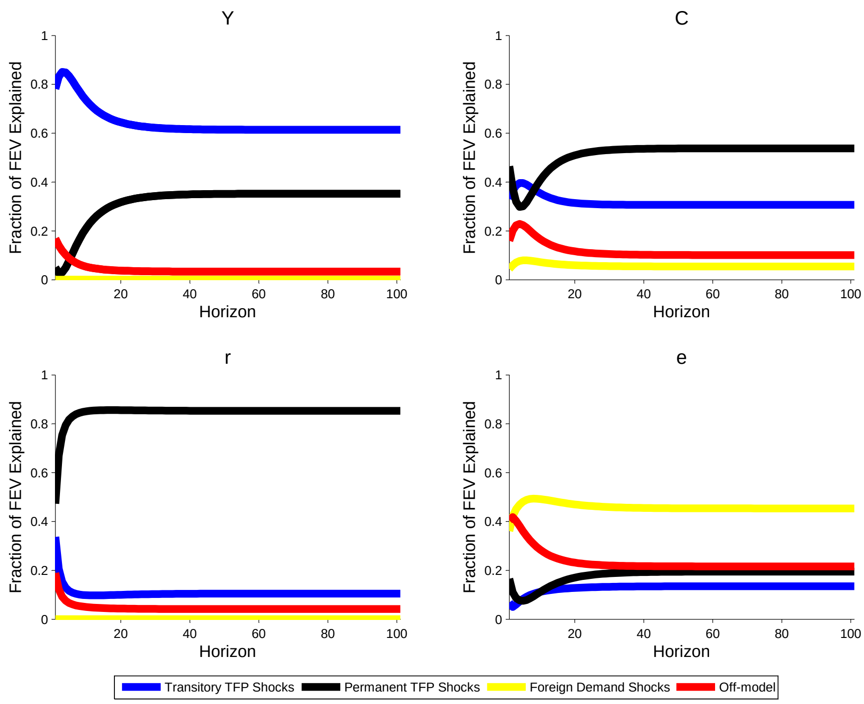
Notes: The table shows the random walk component of the Solow residual and the ratio of volatilities $\frac{\sigma_g}{\sigma_z}$ calculated at the median of the posterior distribution.

component does not differ substantially across models. It is somewhat higher in the model with liability dollarization than in the benchmark model for Turkey, whereas it is the reverse for South Africa. Moreover, we find that the RWC is smaller in developed economies than in EMEs. This finding corroborates the result of Aguiar and Gopinath (2007) and explains why our analysis finds support for their hypothesis that *"the cycle is the trend"* in emerging markets.

A.4 Forecast Error Variance Decomposition

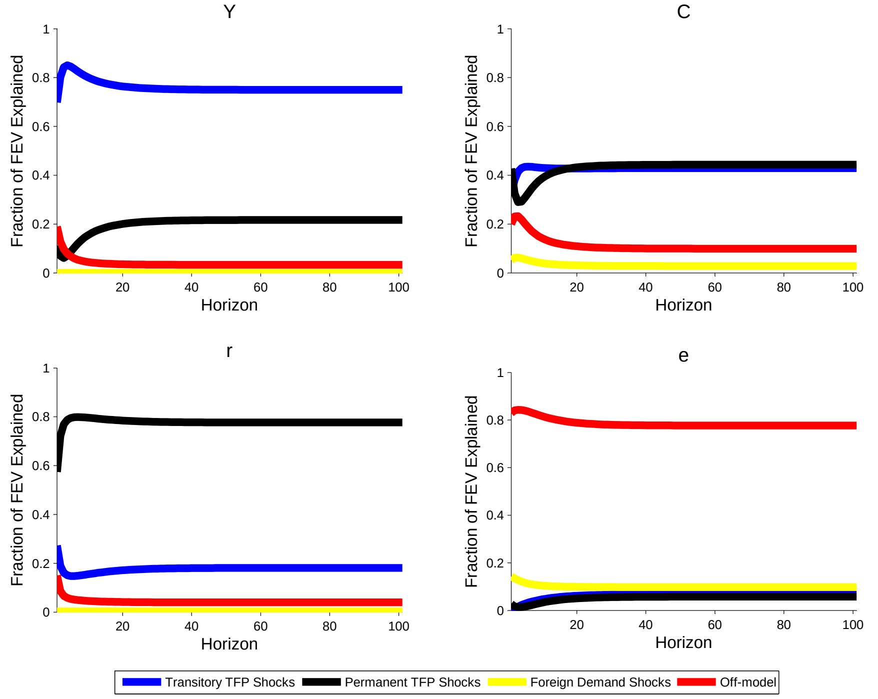
This section presents forecast error variance decompositions for the three EMEs and developed economies in our analysis. In each specification, we focus on the respective model parametrized at the median of the posterior distributions. Figures A.16 to A.21 display the variance decompositions of the benchmark economy as well as the model with liability dollarization for Mexico, South Africa, and Turkey. Figures A.13 to A.15, show the variance decompositions of the benchmark model for Canada, Sweden, and Switzerland.

Figure A.13: Forecast Error Variance Decomposition – Canada



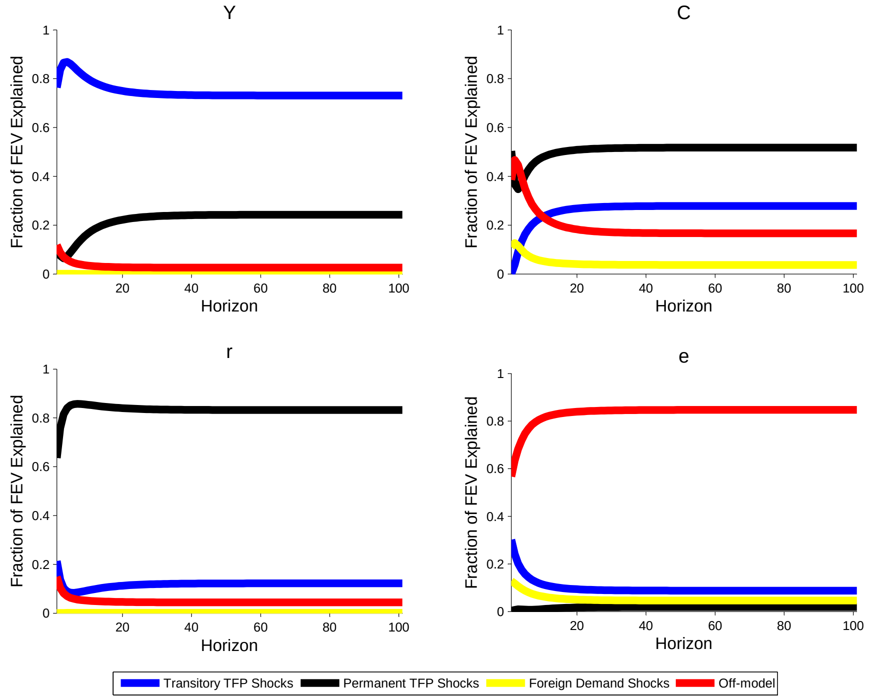
Notes: Forecast error variance decomposition based on median outcomes of the posterior distribution estimated for Canada.

Figure A.14: Forecast Error Variance Decomposition – Sweden



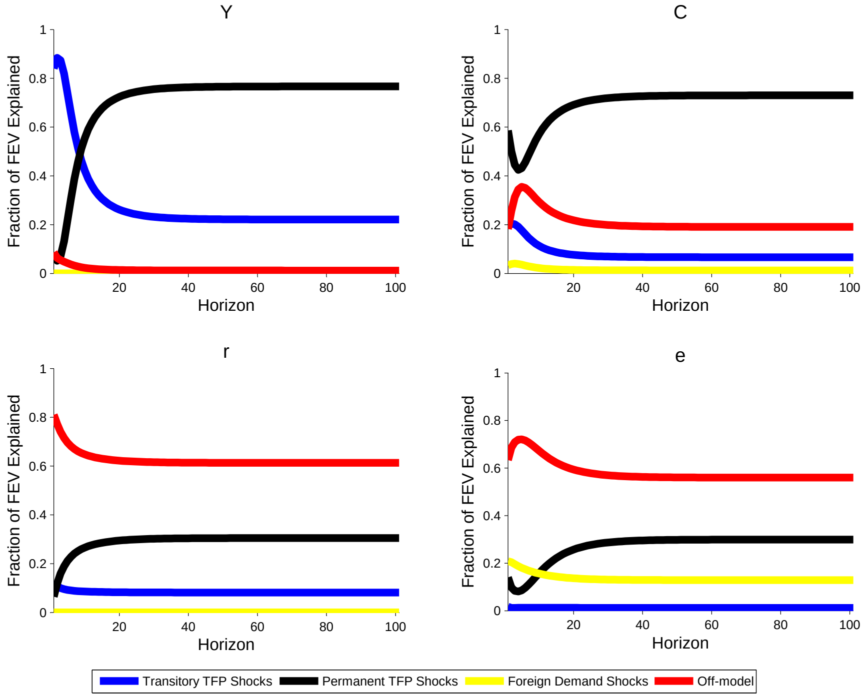
Notes: Forecast error variance decomposition based on median outcomes of the posterior distribution estimated for Sweden.

Figure A.15: Forecast Error Variance Decomposition – Switzerland



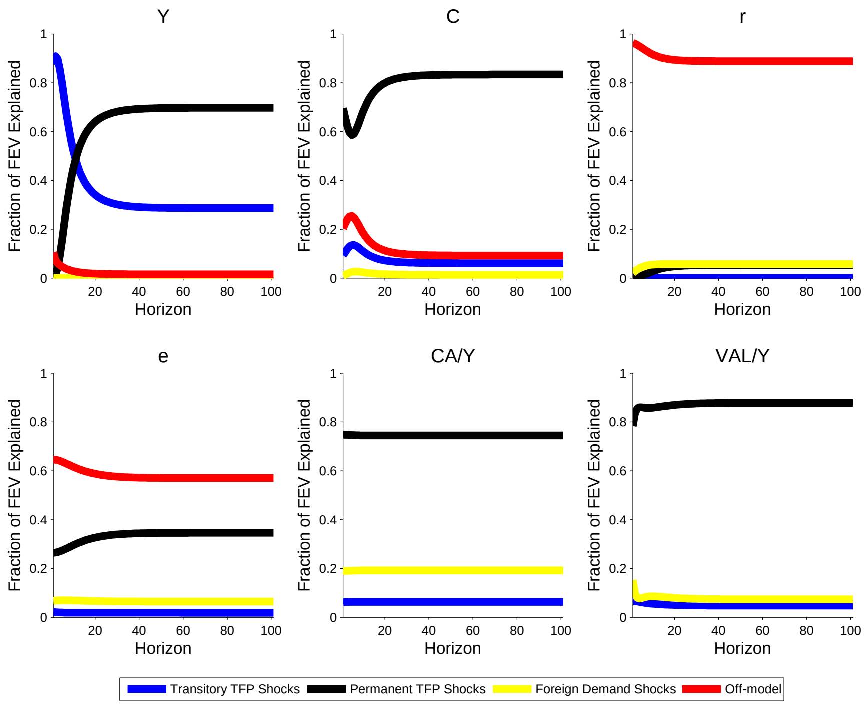
Notes: Forecast error variance decomposition based on median outcomes of the posterior distribution estimated for Switzerland.

Figure A.16: Forecast Error Variance Decomposition – Mexico Benchmark



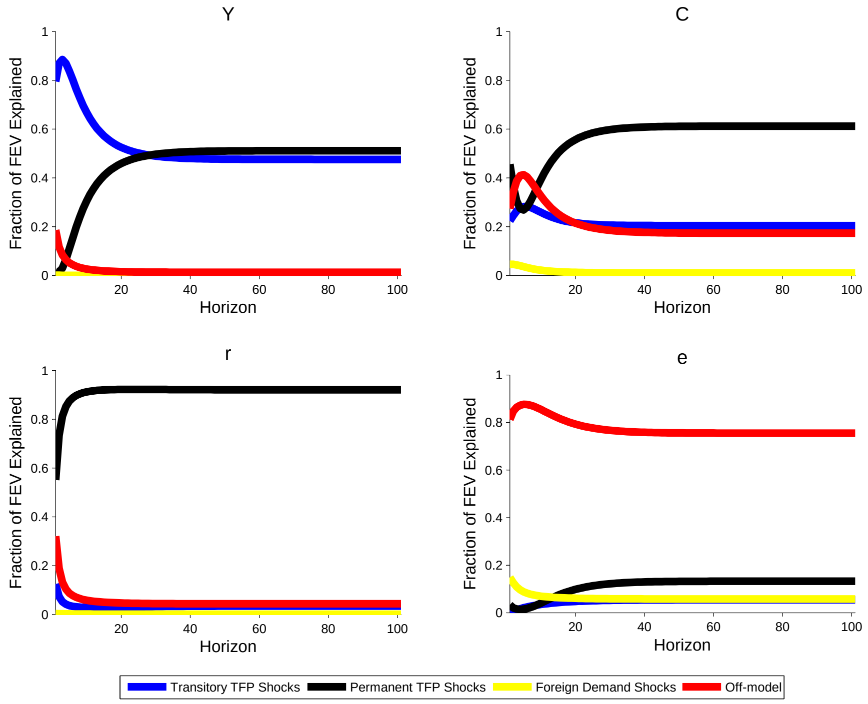
Notes: Forecast error variance decomposition based on median outcomes of the posterior distribution for the benchmark model estimated for Mexico.

Figure A.17: Forecast Error Variance Decomposition – Mexico L. Dollarization



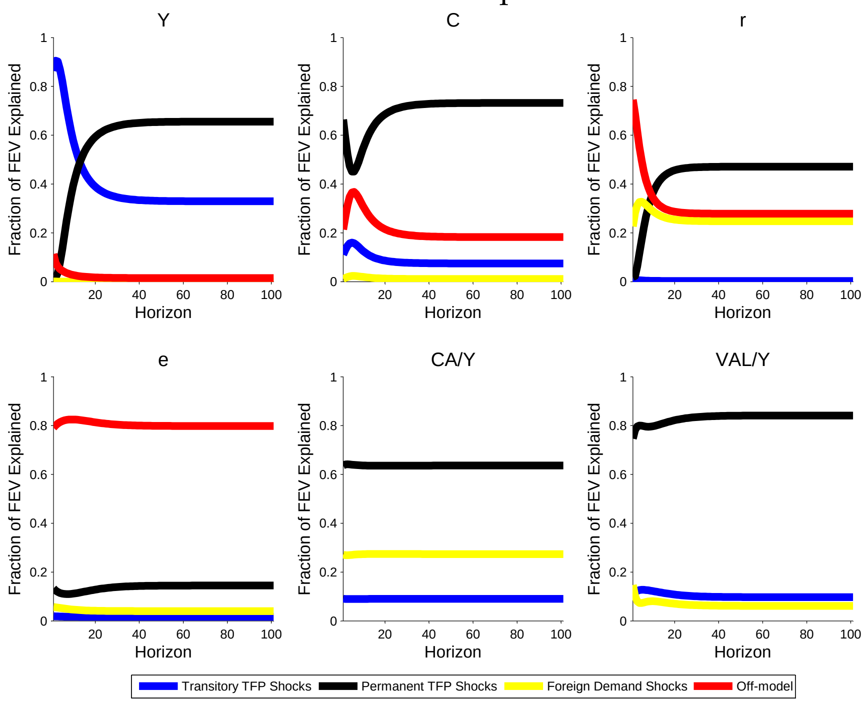
Notes: Forecast error variance decomposition based on median outcomes of the posterior distribution for the liability dollarization model estimated for Mexico.

Figure A.18: Forecast Error Variance Decomposition – S. Africa Benchmark



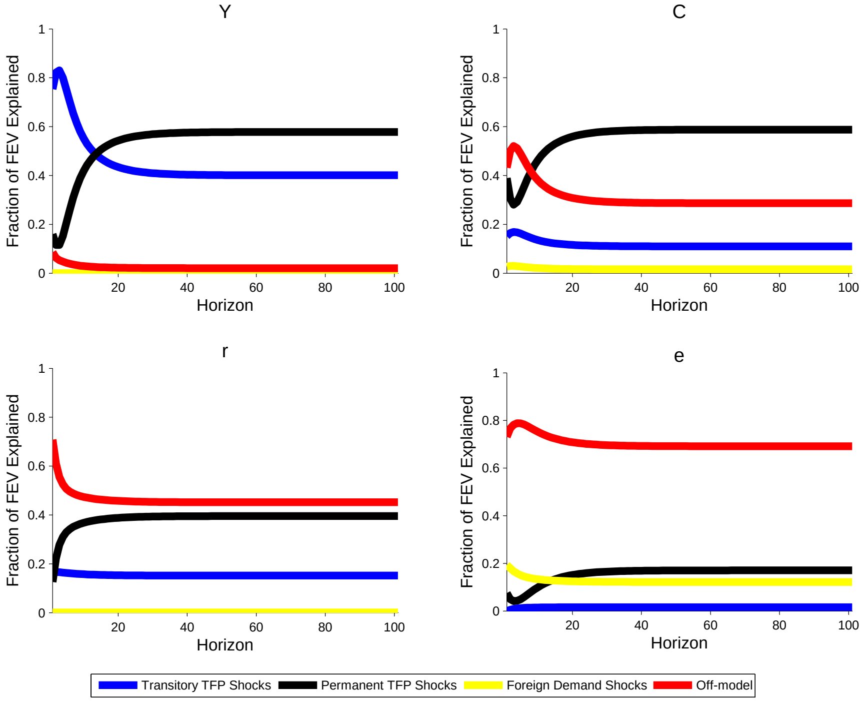
Notes: Forecast error variance decomposition based on median outcomes of the posterior distribution for the benchmark model estimated for South Africa.

Figure A.19: Forecast Error Variance Decomposition – S. Africa L. Dollarization



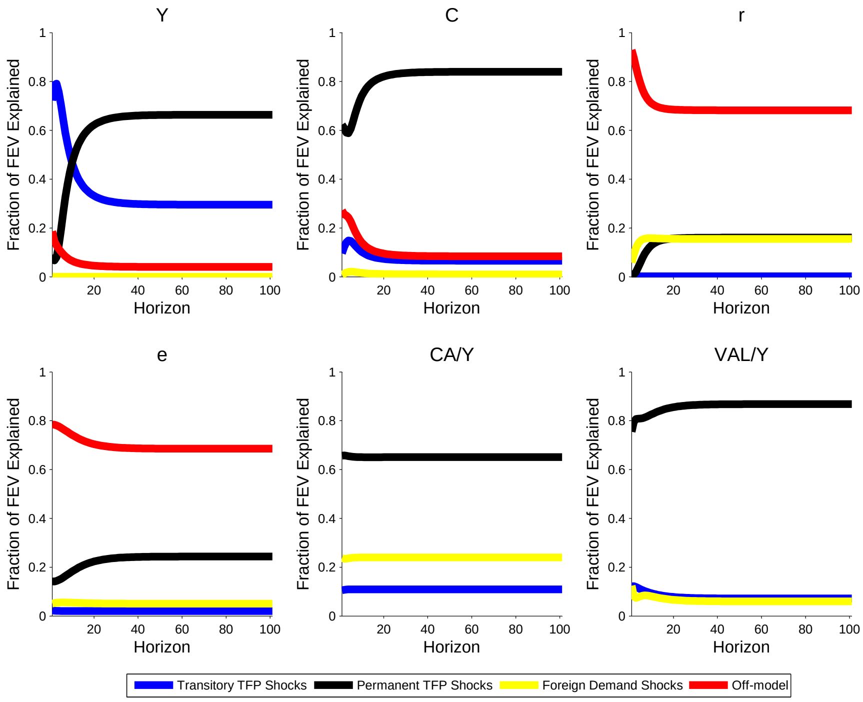
Notes: Forecast error variance decomposition based on median outcomes of the posterior distribution for the liability dollarization model estimated for South Africa.

Figure A.20: Forecast Error Variance Decomposition – Turkey Benchmark



Notes: Forecast error variance decomposition based on median outcomes of the posterior distribution for the benchmark model estimated for Turkey.

Figure A.21: Forecast Error Variance Decomposition – Turkey L. Dollarization



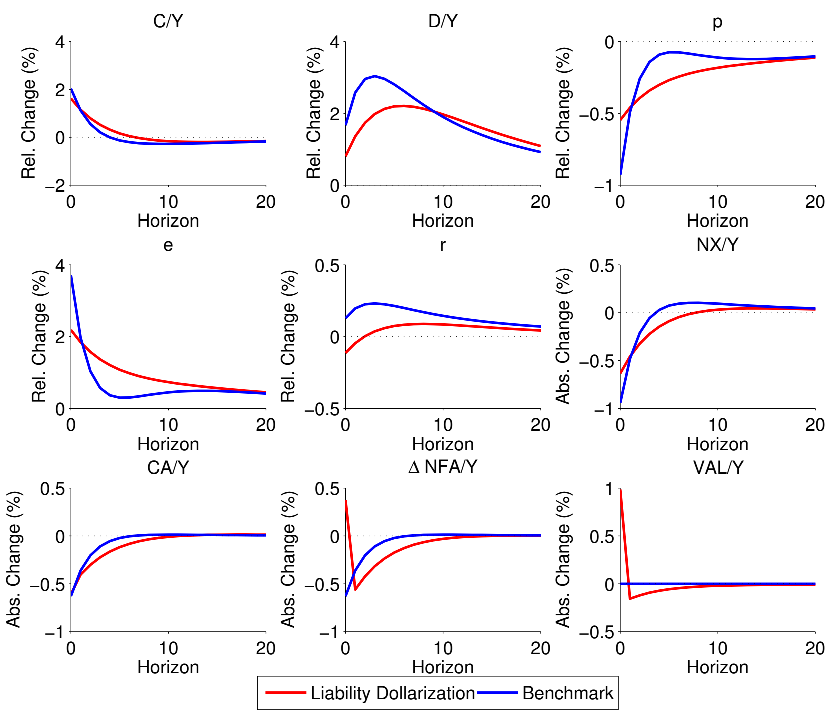
Notes: Forecast error variance decomposition based on median outcomes of the posterior distribution for the liability dollarization model estimated for Turkey.

A.5 Impulse Responses

This section contrasts the impulse responses of the model with liability dollarization with those implied by the benchmark model. For this purpose, we choose the same parametrization for both models. In particular, we calibrate the debt–elasticity of the interest rate ψ and the parameters governing the exogenous processes at the median of the posterior distributions estimated for Mexico in the liability dollarization setup. That is, we set $\psi = 0.216$, $\rho_z = 0.708$, $\rho_z = 0.790$, and $\rho_z = 0.547$.

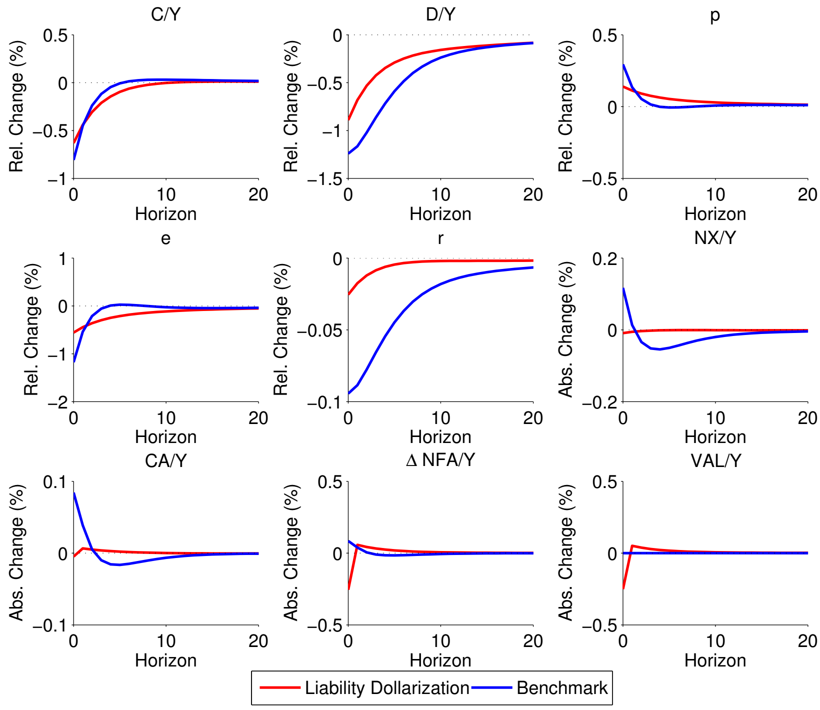
Figures A.22, A.23, and A.24 show the impulse responses after a one percent shock to the permanent productivity process, transitory productivity process, and foreign consumption, respectively.

Figure A.22: Impulse Responses to a Permanent Shock



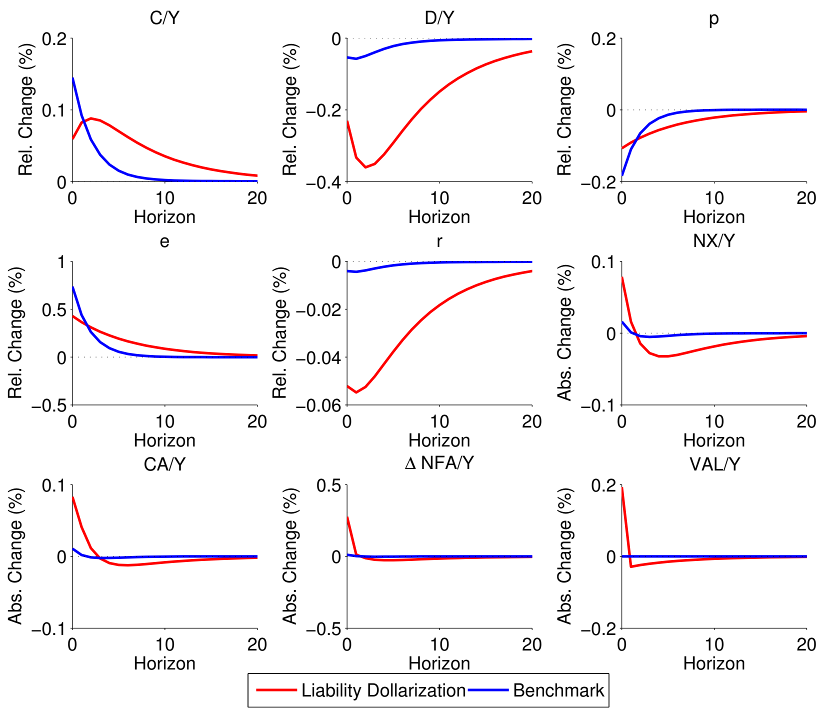
Notes: Impulse responses to a one percent permanent productivity shock in benchmark and liability dollarization model.

Figure A.23: Impulse Responses to a Transitory Shock



Notes: Impulse responses to a one percent transitory productivity shock in benchmark and liability dollarization model.

Figure A.24: Impulse Responses to a Foreign Demand Shock



Notes: Impulse responses to a one percent foreign demand shock in benchmark and liability dollarization model.

A.6 Business Cycle Moments

Table A.3 shows model implied business cycle moments and their empirical counterparts. The table complements the table presented in Section 6.3 in the main text. Here, we simulate the benchmark and the liability dollarization model, each evaluated at the median of the respective posterior distributions, for our three EMEs. Again, we generate time series with 100 observations and subsequently compute sample moments based on the detrended series of our variables. Table A.3 reports the median of our calculated moments across all 5,000 simulations.

Table A.3: Business Cycle Moments in Emerging Market Economies

	Data	Liability Dollarization	Benchmark	Data	Liability Dollarization	Benchmark	Data	Liability Dollarization	Benchmark
		MEXICO			**S. AFRICA**			**TURKEY**	
$\sigma(Y)$	2.42	5.31	5.82	1.60	4.25	5.57	3.70	6.30	6.51
$\sigma(C)$	3.68	6.71	7.05	2.46	5.08	5.60	5.72	7.65	7.12
$\sigma(NX/Y)$	6.63	1.58	0.97	4.04	0.95	0.53	3.42	1.46	0.95
$\sigma(e)$	9.63	7.71	6.78	8.70	5.05	5.47	9.54	7.47	7.14
$\sigma(C)/\sigma(Y)$	1.52	1.57	1.47	1.54	1.41	1.01	1.55	1.45	1.20
$\rho(C, Y)$	0.74	0.77	0.92	0.67	0.82	0.91	0.62	0.86	0.92
$\rho(NX/Y, Y)$	−0.17	−0.10	−0.45	−0.40	−0.19	−0.32	−0.56	−0.27	−0.52
$\rho(e, NX/Y)$	−0.31	−0.62	−0.25	−0.12	−0.43	−0.06	−0.45	−0.48	−0.19
$\rho(Y_t, Y_{t-1})$	0.78	0.88	0.89	0.81	0.90	0.96	0.73	0.83	0.83
$\rho(C_t, C_{t-1})$	0.75	0.84	0.83	0.83	0.86	0.90	0.70	0.79	0.76
$\rho((NX/Y)_t, (NX/Y)_{t-1})$	0.97	0.69	0.29	0.85	0.67	0.32	0.84	0.57	0.17
$\rho(e_t, e_{t-1})$	0.79	0.83	0.76	0.80	0.85	0.84	0.62	0.81	0.74
$\rho((VAL/Y)_t, (CA/Y)_t)$	−0.58	−0.34		−0.75	−0.30		−0.05	−0.38	
$\rho((VAL/Y)_t, e_t)$	0.45	0.29		−0.31	0.28		0.19	0.30	

Notes: Standard deviations are expressed in percentages except for the model implied standard deviation of the net exports to output ratio, which is expressed in percentage points. Empirical moments are calculated using quarterly data taken from the IFS, apart from those involving valuation effects for which only annual data from Lane and Milesi-Ferretti (2007) are available. All series, except for the net exports over output ratio and valuation effects, are real per capita variables, have been logged, seasonally adjusted and filtered using the HP filter with smoothing parameter $\lambda = 1,600$. Theoretical moments are based on sample moments of model generated data. Each theoretical economy is simulated 5,000 times with a sample size of 100. Median outcomes are reported.

Appendix B

Appendix to "A Small Open Economy in the Great Depression: the Case of Switzerland"

B.1 Optimality Conditions

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- Consumption Composite Index:

$$C_t = \left((1-\gamma)^{\frac{1}{a}} \left(C_t^h\right)^{\frac{a-1}{a}} + \gamma^{\frac{1}{a}} \left(C_t^f\right)^{\frac{a-1}{a}}\right)^{\frac{a}{a-1}} \tag{B.1}$$

- Consumer Price Index:

$$P_t = \left((1-\gamma)\left(P_t^h\right)^{1-a} + \gamma\left(P_t^f\right)^{1-a}\right)^{\frac{1}{1-a}} \tag{B.2}$$

- Demand Functions:

$$C_t^h = \left(\frac{P_t^h}{P_t}\right)^{-a} C_t(1-\gamma) \tag{B.3}$$

$$C_t^f = \left(\frac{P_t^f}{P_t}\right)^{-a} C_t\gamma \tag{B.4}$$

- Intratemporal Labor Leisure Trade–off:

$$\frac{N_t^{\eta}}{C_t^{-\sigma}} = \frac{W_t}{P_t} \tag{B.5}$$

- Terms of Trade:

$$\Delta_t = \frac{P_t^f}{P_t^h} \tag{B.6}$$

- Real Exchange Rate:

$$\Phi_t = \frac{P_t^f}{P_t} \tag{B.7}$$

- Real Marginal (average) Cost of Production:

$$\Psi_t = \frac{W_t}{P_t^h} \tag{B.8}$$

- Aggregate Production Function:

$$Y_t = \frac{N_t}{\zeta_t} \tag{B.9}$$

- Calvo Pricing:

$$A_{1,t} = Y_t \Psi_t + \omega\beta \mathrm{E}_t \left[\left(\frac{C_{t+1}}{C_t} \right)^{-\sigma} (\Pi_{t+1})^{-1} (\Pi_{t+1}^h)^{\theta+1} A_{1,t+1} \right] \tag{B.10}$$

$$A_{2,t} = Y_t + \omega\beta \mathrm{E}_t \left[\left(\frac{C_{t+1}}{C_t} \right)^{-\sigma} (\Pi_{t+1})^{-1} (\Pi_{t+1}^h)^{\theta} A_{2,t+1} \right] \tag{B.11}$$

- Domestic Inflation:

$$1 = \left((1-\omega) \left(\frac{\theta A_{1,t}}{(\theta-1) A_{2,t}} \right)^{1-\theta} + \omega \left(\Pi_t^h \right)^{\theta-1} \right)^{\frac{1}{1-\theta}} \tag{B.12}$$

- Exports:

$$EX_t = C_t^{h\star} = \gamma \Delta_t^a Y_t^\star \tag{B.13}$$

- Imports:

$$IM_t = \Delta_t \left(\frac{P_t^f}{P_t} \right)^{-a} \gamma C_t \tag{B.14}$$

- Inflation Rate of Domestic Goods

$$\Pi^h_{t+1} = \frac{P^h_{t+1}}{P^h_t} \tag{B.15}$$

- Domestic Inflation Rate

$$\Pi_{t+1} = \frac{P_{t+1}}{P_t} \tag{B.16}$$

- National Accounting Identity:

$$Y_t = C^h_t + C^{h\star}_t \tag{B.17}$$

- International Risk Sharing Condition:

$$\left(\frac{C^\star_t}{C_t}\right)^{-\sigma} = \Phi_t \tag{B.18}$$

- Foreign Demand (Exogenous Process):

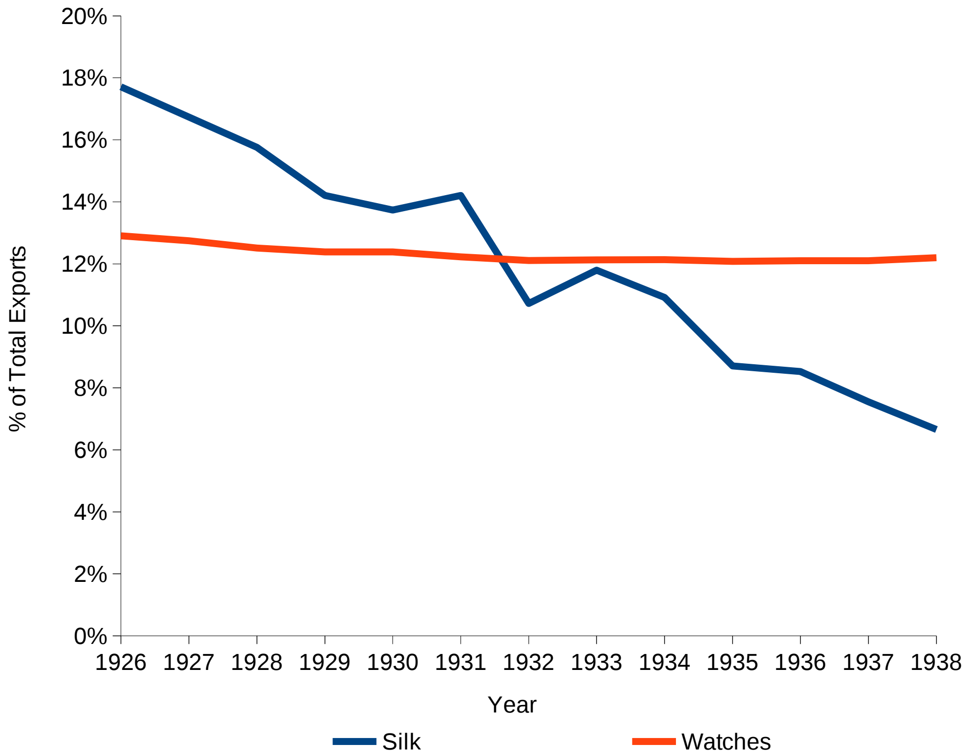
$$\ln(Y^\star_t) = (1-\rho_\star)\ln(Y^\star) + \rho_\star \ln(Y^\star_{t-1}) + \epsilon_{\star,t}, \text{ with } \epsilon^\star_t \sim N(0, \sigma^2_\star) \tag{B.19}$$

- Terms of Trade (Exogenous Process):

$$\ln(\Delta_t) = \rho^\delta \ln(\Delta_{t-1}) + \epsilon^\delta_t, \text{ with } \epsilon^\delta_t \sim N(0, \sigma^2_\delta) \tag{B.20}$$

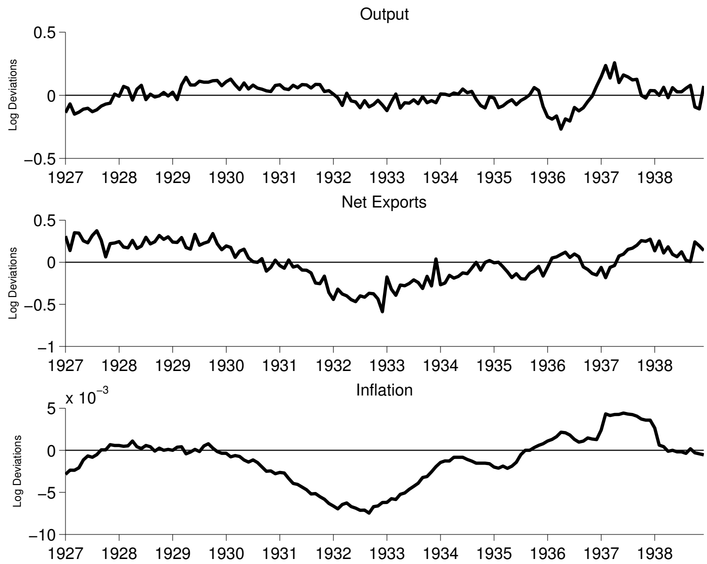
B.2 Supplementary Plots

Figure B.1: Export Shares



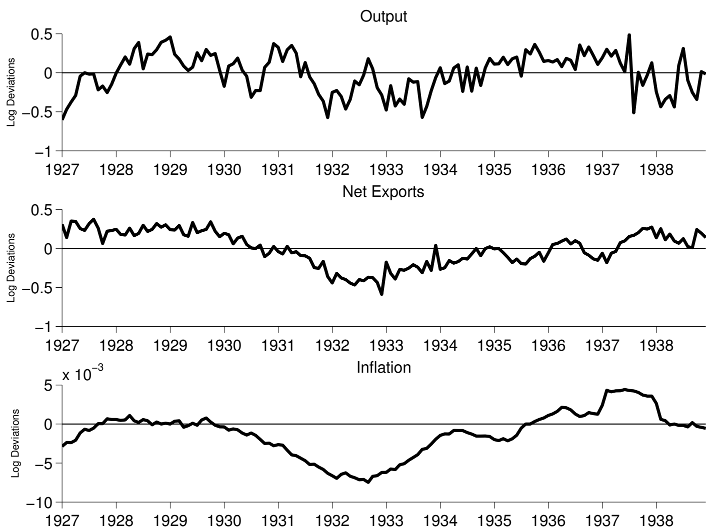
Notes: For details and sources see Section 3.3.

Figure B.2: Data (Output SBB Freight)



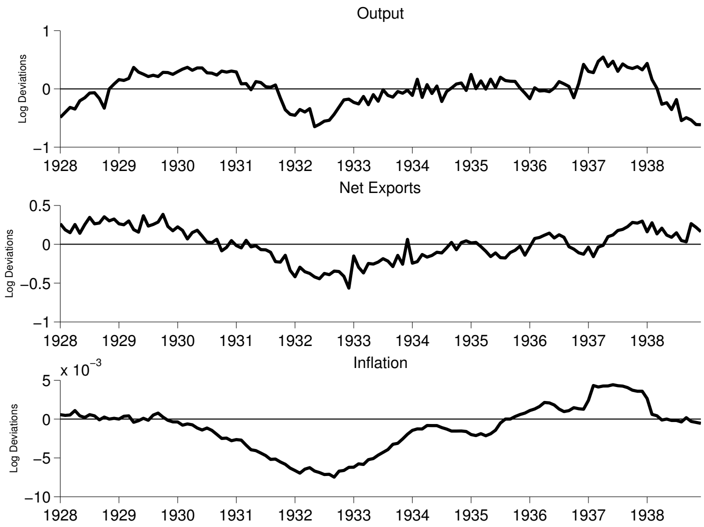
Notes: For details and sources see Section 3.3.

Figure B.3: Data (Output Silk Production)



Notes: For details and sources see Section 3.3.

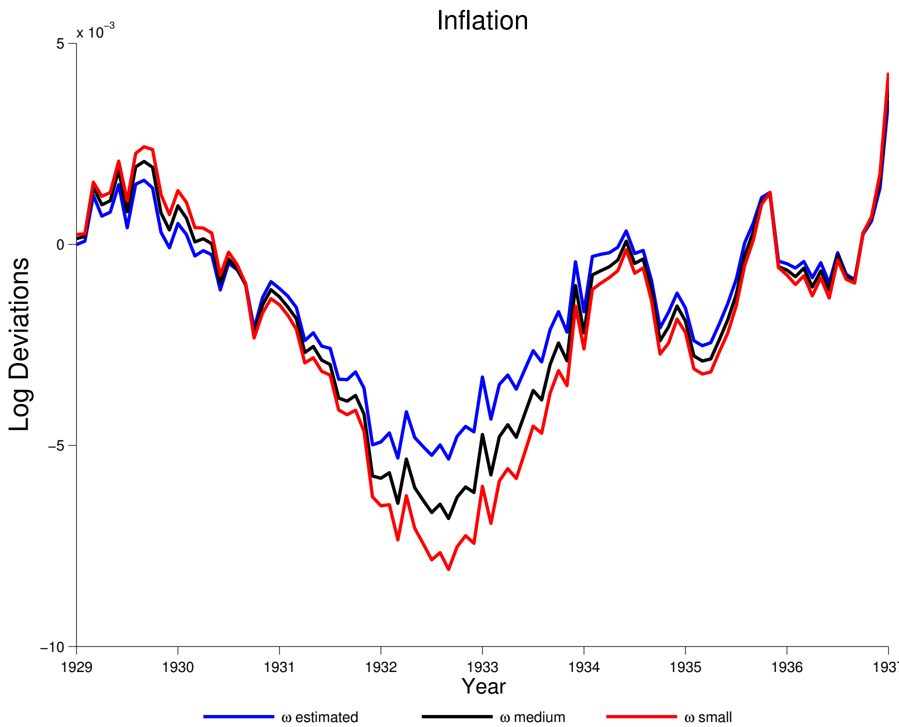
Figure B.4: Data (Output Watch Production)



Notes: For details and sources see Section 3.3.

B.3 Additional Estimation Results

Figure B.5: Counterfactual Price Rigidities



Notes: Results are based on 5,000 draws from the posterior distribution, median outcomes are reported. Small ω implies an average duration of prices being effective of 50 months, while medium ω implies 100 months. ω estimated implies a median duration of prices of 182 months.

Table B.1: Posterior Distributions of Non–Structural Parameters

Parameter	Prior Dist.	Median	90% Bands	Gewekes χ^2
a_{11}	stationary	0.918	[0.745,1.082]	0.948
a_{21}	stationary	-0.774	[-1.040,-0.550]	0.693
a_{31}	stationary	-0.011	[-0.017,-0.006]	0.322
a_{12}	stationary	0.257	[0.126,0.379]	0.431
a_{22}	stationary	-0.017	[-0.200,0.172]	0.358
a_{23}	stationary	0.001	[-0.004,0.006]	0.588
a_{13}	stationary	0.000	[-0.068,0.019]	0.451
a_{23}	stationary	0.001	[-0.090,0.352]	0.515
a_{33}	stationary	0.000	[-0.001,0.004]	0.581
$\sqrt{\text{VAR}(\kappa_y)}$	positive definite	0.050	[0.045,0.056]	0.282
$\sqrt{\text{VAR}(\kappa_{nx})}$	positive definite	0.067	[0.060,0.074]	0.349
$\sqrt{\text{VAR}(\kappa_\pi)}$	positive definite	0.001	[0.000,0.001]	0.457
$\text{COV}(\kappa_y, \kappa_{nx})$	positive definite	-0.001	[-0.002,-0.001]	0.700
$\text{COV}(\kappa_y, \kappa_\pi)$	positive definite	0.000	[0.000,0.000]	0.446
$\text{COV}(\kappa_{nx}, \kappa_\pi)$	positive definite	0.000	[0.000,0.000]	0.564

Notes: The VAR matrix is restricted to have a maximum absolute eigenvalue of 0.6 and its entries are only allowed to take on absolute values smaller or equal to 2. The variance–covariance matrix of the measurement error is restricted to be positive definite and its entries on the main diagonal are only allowed to take on values, which are not larger than 60 percent of the variance of the corresponding data series. Results are based on 400,000 draws, where the first 150,000 are discarded as burn–in draws. SBB freight data is used for industrial production.

Appendix C

Appendix to “The Role of Labor Market Imperfections and Credit Constraints in the German Great Depression”

C.1 Model

C.1.1 Full Model

The economy is represented by:

Production Technology

$$y_t = z_t k_t^{\alpha} (h_t)^{1-\alpha} \qquad \text{Production Function}$$

$$z_t = z^{1-\rho^z} z_{t-1}^{\rho_z} \exp(\epsilon_t^z) \qquad \text{Transitory Technology Process}$$

$$k_{t+1} = (1-\delta)k_t + i_t - \frac{\phi}{2}\left(\frac{k_{t+1}}{k_t} - 1\right)^2 k_t \qquad \text{Law of Motion of Capital}$$

$$r_t = \frac{\partial y_t}{\partial k_t} = \alpha \frac{y_t}{k_t} \qquad \text{Return to Capital}$$

$$w_t = \frac{\partial y_t}{\partial h_t} = (1-\alpha)\frac{y_t}{h_t} \qquad \text{Wage Rate}$$

with $\epsilon_t^z \sim \mathcal{N}(0, \sigma_z^2)$.

Heterogeneous Agents: Aggregation

$$k_t = \lambda k_t^k \qquad \text{Capital Index}$$

$$h_t = \lambda h_t^k + (1-\lambda) h_t^w \qquad \text{Labor Index}$$

$$c_t = \lambda c_t^k + (1-\lambda) c_t^w \qquad \text{Consumption Index}$$

$$i_t = \lambda i_t^k \qquad \text{Investment Index}$$

$$d_t = \lambda d_t^k \qquad \text{Foreign Debt Index}$$

Heterogeneous Agents: Utility Maximization

$u(c_t^i, 1-h_t^i) = \ln(c_t^i) + \eta \ln(1-h_t^i)$ Agent's Period Utility Function for $i = k, w$

$\tau_t w_t h_t^k + r_t k_t^k + d_{t+1}^k = c_t^k + i_t^k + (1+r_{t-1}^d)d_t^k + t_t^g + t_t^{t,k}$ Capitalist's Budget Constr.

$k_{t+1}^k = (1-\delta)k_t^k + i_t^k - \frac{\phi}{2}\left(\frac{k_{t+1}^k}{k_t^k} - 1\right)^2 k_t^k$ Law of Motion of Capitalist's Capital

$\tau_t w_t h_t^w = c_t^w + t_t^g + t_t^{t,w}$ Workers's Budget Constraint

Maximization Problem Capitalist

The capitalist's optimization problem at time t can be stated as

$$
\begin{aligned}
&\max_{\{c_\gamma^k, h_\gamma^k, k_{\gamma+1}^k, d_{\gamma+1}^k\}} \mathrm{E}_t \sum_{\gamma=t}^{\infty} \beta^{\gamma-t}(u(c_\gamma^k, 1-h_\gamma^k)) \\
&\text{s.t.} \qquad \tau_\gamma w_\gamma h_\gamma^k + r_\gamma k_\gamma^k + d_{\gamma+1}^k \geq \\
&c_\gamma^k + k_{\gamma+1}^k - (1-\delta)k_\gamma^k + \frac{\phi}{2}\left(\frac{k_{\gamma+1}^k}{k_\gamma^k} - 1\right)^2 k_\gamma^k + (1+r_{\gamma-1}^d)d_\gamma^k + t_\gamma^{t,k} + t_\gamma^g
\end{aligned}
$$

taking as given k_t^k, d_t^k, z_t, τ_t, g_t, as well as the transversality condition $\lim_{j\to\infty} \mathrm{E}_t\left[\prod_{s=0}^{j-2} \frac{d_{t+j}}{1+r_{t+s}^d}\right] = 0$. Capitalist's Lagrangian:

$$
\begin{aligned}
\mathcal{L} = &\mathrm{E}_t \Bigg[\sum_{\gamma=t}^{\infty} \beta^{\gamma-t}\Big(u(c_\gamma^k, 1-h_\gamma^k) + \mu_\gamma^k\Big(\tau_\gamma w_\gamma h_\gamma^k + r_\gamma k_\gamma^k + d_{\gamma+1}^k \\
&-c_\gamma^k - k_{\gamma+1}^k + (1-\delta)k_\gamma^k - \frac{\phi}{2}\left(\frac{k_{\gamma+1}^k}{k_\gamma^k} - 1\right)^2 k_\gamma^k - (1+r_{\gamma-1}^d)d_\gamma^k - t_\gamma^{t,k} - t_\gamma^g\Bigg]
\end{aligned}
$$

with the following first order conditions:

$$
\begin{aligned}
&\text{(I)} && \frac{\partial \mathcal{L}}{\partial c_t^k} = \frac{\partial u(c_t^k, 1-h_t^k)}{\partial c_t^k} - \mu_t^k = 0 \\
& && \Leftrightarrow \quad \frac{\partial u(c_t^k, 1-h_t^k)}{\partial c_t^k} = \mu_t^k \\
& && \Rightarrow \quad \mathrm{E}_t\left[\frac{\partial u(c_{t+1}^k, 1-h_{t+1}^k)}{\partial c_{t+1}^k}\right] = \mathrm{E}_t\left[\mu_{t+1}^k\right] \\
&\text{(II)} && \frac{\partial \mathcal{L}}{\partial h_t^k} = \frac{\partial u(c_t^k, 1-h_t^k)}{\partial h_t^k} + \mu_t^k \tau_t w_t = 0 \\
& && \Leftrightarrow \quad -\frac{\partial u(c_t^k, 1-h_t^k)}{\partial h_t^k}\frac{1}{\mu_t^k} = \tau_t w_t \\
&\text{(III)} && \frac{\partial \mathcal{L}}{\partial k_{t+1}^k} = -\mu_t^k\left[1 + \phi\left(\frac{k_{t+1}^k}{k_t^k} - 1\right)\right] + \beta \mathrm{E}_t\left[\mu_{t+1}^k\Big((r_{t+1} + (1-\delta))\right. \\
& && \quad \left. + \phi\left(\frac{k_{t+2}^k}{k_{t+1}^k} - 1\right)\frac{k_{t+2}^k}{k_{t+1}^k} - \frac{\phi}{2}\left(\frac{k_{t+2}^k}{k_{t+1}^k} - 1\right)^2\Big)\right] = 0 \\
& && \Leftrightarrow \quad \mu_t^k\left[1 + \phi\left(\frac{k_{t+1}^k}{k_t^k} - 1\right)\right] \\
& && \quad = \beta \mathrm{E}_t\left[\mu_{t+1}^k\left(r_{t+1} + (1-\delta) + \phi\left(\frac{k_{t+2}^k}{k_{t+1}^k} - 1\right)\frac{k_{t+2}^k}{k_{t+1}^k} - \frac{\phi}{2}\left(\frac{k_{t+2}^k}{k_{t+1}^k} - 1\right)^2\right]\right. \\
&\text{(IV)} && \frac{\partial \mathcal{L}}{\partial d_{t+1}^k} = \mu_t^k - \beta \mathrm{E}_t\left[\mu_{t+1}^k(1 + r_t^d)\right] = 0 \\
& && \Leftrightarrow \quad \mu_t^k = \beta \mathrm{E}_t\left[\mu_{t+1}^k(1 + r_t^d)\right] \\
&\text{(V)} && \frac{\partial \mathcal{L}}{\partial \mu_t^k} = \tau_t w_t h_t^k + r_t k_t^k + d_{t+1}^k \\
& && \quad - c_t^k - k_{t+1}^k + (1-\delta)k_t^k + \frac{\phi}{2}\left(\frac{k_{t+1}^k}{k_t^k} - 1\right)^2 k_t^k - (1 + r_{t-1}^d)d_t^k - t_t^{t,k} - t_t^g = 0 \\
& && \Leftrightarrow \quad \tau_t w_t h_t^k + r_t k_t^k + d_{t+1}^k = \\
& && \quad c_t^k + k_{t+1}^k - (1-\delta)k_t^k - \frac{\phi}{2}\left(\frac{k_{t+1}^k}{k_t^k} - 1\right)^2 k_t^k + (1 + r_{t-1}^d)d_t^k + t_t^{t,k} + t_t^g
\end{aligned}
$$

Maximization Problem Worker

The worker's optimization problem at time t can be stated as

$$\max_{\{c_\gamma^w, h_\gamma^w\}} \mathrm{E}_t \sum_{\gamma=t}^{\infty} \beta^{\gamma-t}(u(c_\gamma^k, 1-h_\gamma^k))$$
$$\text{s.t.} \quad \tau_\gamma w_\gamma h_\gamma^w \geq c_\gamma^w + t_\gamma^{t,w} + t_\gamma^g$$

taking as given k_t, d_t, z_t, τ_t, as well as the transversality condition $\lim_{j\to\infty} \mathrm{E}_t \left[\prod_{s=0}^{j-2} \frac{d_{t+j}}{1+r_{t+s}}\right] = 0$. Worker's Lagrangian:

$$\mathcal{L} = \mathrm{E}_t \left[\sum_{\gamma=t}^{\infty} \beta^{\gamma-t}\Big(u(c_\gamma^w, 1-h_\gamma^w) + \mu_\gamma^w\Big(\tau_\gamma w_\gamma h_\gamma^w - c_\gamma^w - t_\gamma^{t,w} - t_\gamma^g\Big)\Big)\right]$$

with the following first order conditions:

$$
\begin{aligned}
&\text{(I)} \qquad \frac{\partial \mathcal{L}}{\partial c_t^w} = \frac{\partial u(c_t^w, 1-h_t^w)}{\partial c_t^w} - \mu_t^w = 0 \\
&\Leftrightarrow \qquad \frac{\partial u(c_t^w, 1-h_t^w)}{\partial c_t^w} = \mu_t^w \\
&\Rightarrow \qquad \mathrm{E}_t\left[\frac{\partial u(c_{t+1}^w, 1-h_{t+1}^w)}{\partial c_{t+1}^w}\right] = \mathrm{E}_t\left[\mu_{t+1}^w\right] \\
&\text{(II)} \qquad \frac{\partial \mathcal{L}}{\partial h_t^w} = \frac{\partial u(c_t^w, 1-h_t^w)}{\partial h_t^w} + \mu_t^w \tau_t w_t = 0 \\
&\Leftrightarrow \qquad -\frac{\partial u(c_t^w, 1-h_t^w)}{\partial h_t^w}\frac{1}{\mu_t^w} = \tau_t w_t \\
&\text{(III)} \qquad \frac{\partial \mathcal{L}}{\partial \lambda_t^w} = \tau_t w_t h_t^w - c_t^w - t_t^{t,w} - t_t^g = 0 \\
&\Leftrightarrow \qquad \tau_t w_t h_t^w = c_t^w + t_t^{t,w} + t_t^g
\end{aligned}
$$

Open Economy Characteristics

$$r_t^d = r^d + \psi \left(\exp\left(d_{t+1} - d\right) - 1\right) \qquad \text{International Interest Rate}$$

$$ca_t = -d_{t+1} + (1 + r_t^d)d_t \qquad \text{Current Account}$$

Labor Market Inefficiencies

$$w_t h_t = \tau_t w_t h_t + t_t^t \qquad \text{Wages}$$

$$t_t^t = \lambda t_t^{t,k} + (1-\lambda) t_t^{t,w} \qquad \text{Total Lump-sum transfers}$$

$$t_t^{t,i} = (1-\tau_t) w_t h_t^i \qquad \text{Individual Lump-sum transfers} \qquad \text{for } i = k, w$$

$$\tau_t = \tau^{1-\rho^\tau} \tau_{t-1}^{\rho_\tau} \exp(\epsilon_t^\tau) \qquad \text{Labor Wedge Process}$$

Aggregation

$$t_t^g = g_t \qquad \text{Lump sum taxes}$$

$$g_t = g^{1-\rho^g} g_{t-1}^{\rho_g} \exp(\epsilon_t^g) \qquad \text{Government Spending Process}$$

$$Y_t = w_t h_t + r_t k_t \qquad \text{Market Clearing}$$

$$\lambda \left(\tau_t w_t h_t^k + r_t k_t^k + d_{t+1}^k\right) + (1-\lambda)\left(\tau_t w_t h_t^w\right) =$$

$$\lambda \left(c_t^k + k_{t+1}^k - (1-\delta)k_t^k - \frac{\phi}{2}\left(\frac{k_{t+1}^k}{k_t^k} - 1\right)^2 k_t^k + (1 + r_{t-1}^d)d_t^k + t_t^{t,k} + t_t^g\right)$$

$$+ (1-\lambda)\left(c_t^w + t_t^{t,w} + t_t^g\right)$$

$$\Leftrightarrow \tau_t w_t h_t + r_t k_t + d_{t+1} = c_t + i_t + (1 + r_{t-1}^d)d_t + g_t + \lambda t_t^{t,k} + (1-\lambda) t_t^{t,w}$$

$$\Leftrightarrow y_t = w_t h_t + r_t k_t = c_t + i_t + g_t + ca_t + \underbrace{(\tau_t - 1)w_t h_t + t_t^t}_{=0}$$

$$\Leftrightarrow y_t = c_t + i_t + g_t + ca_t \qquad \text{Aggregate Resource Constraint}$$

C.1.2 Model Summary

Eventually, one can summarize the model, which is described by the following optimality and necessary conditions:

- Production Function

$$y_t = z_t k_t^{\alpha} (h_t)^{1-\alpha} \tag{C.1}$$

- Period t Aggregate Resource Constraint

$$y_t = c_t + i_t + g_t + ca_t \tag{C.2}$$

- Law of Motion of Capital

$$k_{t+1} = (1-\delta)k_t + i_t - \frac{\phi}{2}\left(\frac{k_{t+1}}{k_t} - 1\right)^2 k_t \tag{C.3}$$

- Period t Capitalist's Budget Constraint

$$\tau_t w_t h_t^k + r_t k_t^k + d_{t+1}^k = c_t^k + k_{t+1}^k - (1-\delta)k_t^k - \frac{\phi}{2}\left(\frac{k_{t+1}^k}{k_t^k} - 1\right)^2 k_t^k + (1+r_{t-1}^d)d_t^k + t_t^{t,k} + t_t^g \tag{C.4}$$

- Period t Worker's Budget Constraint

$$\tau_t w_t h_t^w = c_t^w + t_t^{t,w} + t_t^g \tag{C.5}$$

- Investment Euler Equation

$$\begin{aligned}
&\frac{\partial u(c_t^k, 1-h_t^k)}{\partial c_t^k}\left[1 + \phi\left(\frac{k_{t+1}^k}{k_t^k} - 1\right)\right] \\
&= \beta \mathrm{E}_t\left[\frac{\partial u(c_{t+1}^k, 1-h_{t+1}^k)}{\partial c_{t+1}^k}\left(r_{t+1} + (1-\delta) + \phi\left(\frac{k_{t+2}^k}{k_{t+1}^k} - 1\right)\frac{k_{t+2}^k}{k_{t+1}^k} - \frac{\phi}{2}\left(\frac{k_{t+2}^k}{k_{t+1}^k} - 1\right)^2\right]
\end{aligned} \tag{C.6}$$

- Labor–Leisure Trade–off Capitalist

$$-\frac{\frac{\partial u(c_t^k,1-h_t^k)}{\partial h_t^k}}{\frac{\partial u(c_t^k,1-h_t^k)}{\partial c_t^k}} = \tau_t w_t \tag{C.7}$$

- Labor–Leisure Trade–off Worker

$$-\frac{\frac{\partial u(c_t^w,1-h_t^w)}{\partial h_t^w}}{\frac{\partial u(c_t^w,1-h_t^w)}{\partial c_t^w}} = \tau_t w_t \tag{C.8}$$

- Bond Euler Equation

$$\frac{\partial u(c_t^k, h_t^k)}{\partial c_t^k} = \beta \mathrm{E}_t \left[\frac{\partial u(c_{t+1}^k, h_{t+1}^k)}{\partial c_{t+1}} (1 + r_t^d) \right] \tag{C.9}$$

- International Interest Rate Rule

$$r_t^d = r^d + \psi \left(\exp\left(d_{t+1} - d \right) - 1 \right) \tag{C.10}$$

- Current Account

$$ca_t = -d_{t+1} + (1 + r_{t-1}) d_t \tag{C.11}$$

- Transitory Technology Process

$$z_{t+1} = z^{1-\rho_z} z_t^{\rho_z} \exp(\epsilon_{t+1}^z) \tag{C.12}$$

- Government Spending Process

$$g_{t+1} = g^{1-\rho_g} g_t^{\rho_g} \exp(\epsilon_{t+1}^g) \tag{C.13}$$

- Labor Wedge Process

$$\tau_{t+1} = \tau^{1-\rho_\tau} \tau_t^{\rho_\tau} \exp(\epsilon_{t+1}^\tau) \tag{C.14}$$

- Return to Capital

$$r_t = \alpha \frac{y_t}{k_t} \tag{C.15}$$

- Wage Rate

$$w_t = (1-\alpha)\frac{y_t}{h_t} \tag{C.16}$$

- Capital

$$k_t = \lambda k_t^k \tag{C.17}$$

- Debt

$$d_t = \lambda d_t^k \tag{C.18}$$

- Hours

$$h_t = \lambda h_t^k + (1-\lambda)h_t^w \tag{C.19}$$

- Consumption

$$c_t = \lambda c_t^k + (1-\lambda)c_t^w \tag{C.20}$$

- Investment

$$i_t = \lambda i_t^k \tag{C.21}$$

Moreover, note that

$$\frac{\partial u(c_t^i, 1-h_t^i)}{\partial c_t^i} = \frac{1}{c_t^i} \qquad \text{for } i = k, w$$
$$\frac{\partial u(c_t^i, 1-h_t^i)}{\partial h_t^i} = -\frac{\eta}{(1-h_t)} \qquad \text{for } i = k, w$$

C.2 Steady States

C.2.1 Calibration

- r: real return on capital
- δ: depreciation rate
- α: capital share in economy
- λ: share of capitalists in economy

- h: hours
- ϕ: capital adjustment costs
- ψ: debt elasticity of foreign interest rate
- z: TFP
- $\frac{g}{y}$: public expenditure quota
- $\frac{d}{y}$: total economies debt-to-GDP ratio
- τ: steady state labor market wedge

C.2.2 Determining Remaining Steady State Values

- From (C.6), $\beta = \frac{1}{1+r-\delta}$
- From (C.6) and (C.9), $r - \delta = r^d$
- From (C.1) $\frac{k}{y} = \frac{\alpha}{r}$
- From (C.1) $k = \frac{k}{y}^{\frac{1}{1-\alpha}} h$
- From (C.1) $y = (\frac{k}{y})^{-1} k$
- From (C.1) $k^k = \frac{k}{\lambda}$
- From (C.2) $\frac{c}{y} = 1 - \delta\frac{k}{y} - \frac{g}{y} - r^d\frac{d}{y}$
- From (C.3) $i = \delta k$
- From (C.21) $i^k = \frac{i}{\lambda}$
- From (C.16) $w = (1-\alpha)\frac{y}{h}$
- From $c = \frac{c}{y}$
- From $g = \frac{g}{y}$
- From $d = \frac{d}{y}$
- From (C.18) $d^k = \frac{d}{\lambda}$

- From (C.11) $ca = r^d d$
- From (C.4),(C.5),(C.7),(C.8),(C.19), and (C.20) get

  (i) $w(h - h_w) + (r - \delta)k = (c - c^w) + r^d d$

  (ii) $\left(1 - \frac{h-(1-\lambda)h^w}{\lambda}\right)\frac{1}{1-h^w} = \frac{c-(1-\lambda)c^w}{\lambda c^w}$

  and solve for h^w and c^w numerically.

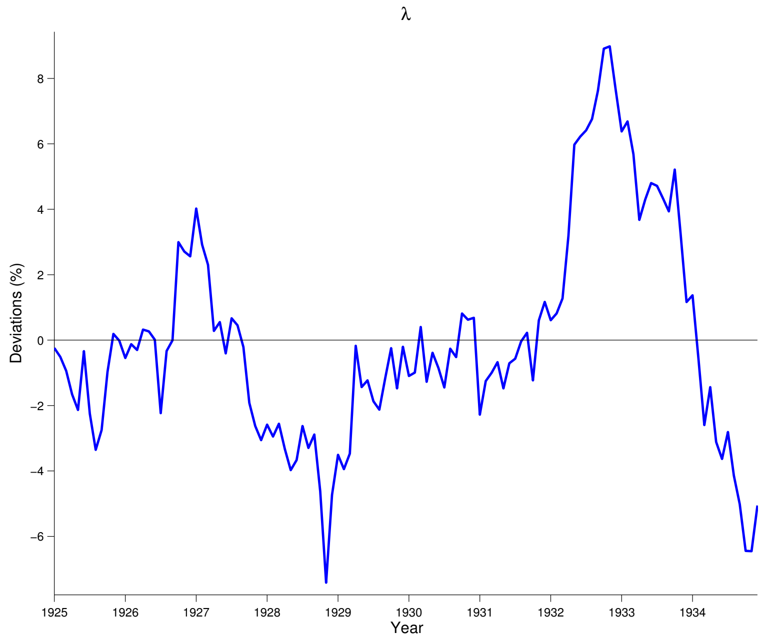
- From (C.19) $h^k = \frac{h-(1-\lambda)h^w}{\lambda}$
- From (C.20) $c^k = \frac{c-(1-\lambda)c^w}{\lambda}$
- From (C.7) $\eta = \frac{\tau w c^k}{1-h^k}$

C.3 Further Estimation Results

Evolution of the Capitalist Share

In order to assess the evolution of the degree of credit constraints, we have also estimated an extended version of the model. In particular, instead of assuming a constant λ over time, we modeled is as an exogenous process and therefore allowed for variations. Figure C.1 presents the evolution of the share of the capitalists, presented in deviations from its steady state level.[1] We observe that from 1927–1932 λ_t was well below steady state, while it took until the end of the reparations until λ_t could reach equilibrium again.

Figure C.1: Time–Varying Share of Capitalists



Results are based on 5,000 draws from the posterior distribution. Mean estimate of λ=0.275, median percent deviations are reported.

[1]Note that the estimation of the extended model yields a median steady state value of λ of 0.275

C.4 Metropolis–Hastings Algorithm within Gibbs Sampler

This section sketches[2] the algorithm I applied to derive posterior distributions of the parameters of interest. The method corresponds to a MCMC simulation using the Metropolis–Hastings (MH) algorithm within the Gibbs sampler. This Bayesian approach is best characterized by Baye's rule:

$$g(\boldsymbol{\theta}|\mathbf{y}) = \frac{f(\mathbf{y}|\boldsymbol{\theta})g(\boldsymbol{\theta})}{f(\mathbf{y})} \propto f(\mathbf{y}|\boldsymbol{\theta})g(\boldsymbol{\theta}), \tag{C.22}$$

where $g(\boldsymbol{\theta})$ is the prior distribution of the parameters containing non–sample information, $f(\mathbf{y}|\boldsymbol{\theta})$ is the likelihood of observing the data given the parameters $\boldsymbol{\theta}$, and $g(\boldsymbol{\theta}|\mathbf{y})$ the posterior density function of the hyperparameters $\boldsymbol{\theta}$ conditional on observing the data $\mathbf{y}$.

As a first step, one needs to decide which parameters to estimate and by which algorithm. The choice is to some extent motivated by the recognizability of the conditional posterior distributions of the parameters. The main idea behind the Gibbs sampling approach is to break the joint posterior distribution into separate conditional posteriors, which have a known analytical representation. This is the case for example for structural autoregressive parameters and their corresponding variances as well as for the measurement error components. Conditional on all other hyperparameters and the data, the solution of the linearized DSGE model yields a linear state space representation and thus recognizable posterior distributions. However, if one is interested in estimating a structural parameter, whose distribution does not take a recognizable form,[3] the Metropolis–Hastings algorithm turns out to be well suited.

To keep this illustration simple, I assume that there is one autoregressive parameter $\theta_{G,1}$ and one variance $\theta_{G,2}$ to be estimated with the Gibbs sampler, while I estimate one additional structural parameter θ_{MH} using the MH algorithm.

[2]For a more detailed description of the Metropolis–Hastings algorithm see e.g. Chib and Greenberg (1995). Concerning the Gibbs sampling approach see Casella and George (1992) or Kim and Nelson (1999).

[3]Most of the remaining hyperparameters of a DSGE model, such as the share of capitalists λ, would be an example.

Note that one could easily apply this setup to a wider range of parameters. Before starting one needs to choose the number of draws (N), select the estimation data $\mathbf{y}$, define prior distributions $g(\boldsymbol{\theta})$, and randomly choose starting values for $\boldsymbol{\theta}_G^0 = (\theta_{G,1}^0, \theta_{G,2}^0)'$ and θ_{MH}^0. The steps of the algorithm are described below.

Start of the algorithm, for $n = 1 : N$

- Gibbs sampling step
  - Solve the DSGE model for given values $\boldsymbol{\theta}_G^{n-1}$ and θ_{MH}^{n-1}
  - Generate time series of unobservable state x_{n-1} using the Kalman Filter
  - Draw $\theta_{G,1}^n$ from conditional posterior, i.e. $g(\theta_{G,1}^n|\theta_{G,2}^{n-1}, \theta_{MH}^{n-1}, \mathrm{x}_{n-1})$
  - Draw $\theta_{G,2}^n$ from conditional posterior, i.e. $g(\theta_{G,2}^n|\theta_{G,1}^n, \theta_{MH}^{n-1}, \mathrm{x}_{n-1})$
- Metropolis–Hastings step
  - Generate candidate $\theta_{MH}^\star$ from (random walk) proposal density:[4]

$$\theta_{MH}^\star = \theta_{MH}^{n-1} + \epsilon_n^{MH} \tag{C.23}$$

  - Conditional on the Gibbs draw, compute likelihoods for

    (i) θ_{MH}^{n-1}: $g(\theta_{MH}^{n-1}|\boldsymbol{\theta}_G^n, \mathbf{y})$

    (ii) $\theta_{MH}^\star$: $g(\theta_{MH}^\star|\boldsymbol{\theta}_G^n, \mathbf{y})$
  - Compute acceptance ratio from moving from θ_{MH}^{n-1} to $\theta_{MH}^\star$, with $q(\cdot)$ being equal to the candidate generating density:

$$\alpha(\theta_{MH}^{n-1}, \theta_{MH}^\star) = \min\left(\frac{g(\theta_{MH}^\star|\boldsymbol{\theta}_G^n, \mathbf{y})q(\theta_{MH}^{n-1}|\theta_{MH}^\star, \mathbf{y})}{g(\theta_{MH}^{n-1}|\boldsymbol{\theta}_G^n, \mathbf{y})q(\theta_{MH}^\star|\theta_{MH}^{n-1}, \mathbf{y})}, 1\right). \tag{C.24}$$

  - If candidate is accepted set $\theta_{MH}^n = \theta_{MH}^\star$, otherwise $\theta_{MH}^n = \theta_{MH}^{n-1}$.
- If $n < N$ go back to Gibbs sampling step

End of the algorithm

[4] $\epsilon_n^{MH} \sim \mathcal{N}(0, \sigma_{MH}^2)$ where σ_{MH}^2 is chosen to obtain a mean acceptance ratio of 25 to 40 percent.

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09/2009 – 09/2014	PhD studies in Economics University of Zurich, Switzerland Supervisors: Ulrich Woitek and Mathias Hoffmann
10/2003 – 03/2009	Diploma (M.Sc.) in Economics University of Konstanz, Germany Supervisors: Ralf Brüggemann and Almuth Scholl

Professional Experience

10/2014 –	Market Infrastructure Expert, European Central Bank (ECB) Frankfurt, Germany
07/2013 – 09/2014	PhD Trainee, European Central Bank (ECB) Frankfurt, Germany
09/2009 – 06/2014	Research and Teaching Assistant, University of Zurich Zurich, Switzerland
04/2009 – 08/2009	Consultant, German Technical Cooperation (GTZ) Vientiane, Lao PDR
11/2008 – 03/2009	Student Research Assistant, University of Konstanz Konstanz, Germany
08/2008 – 10/2008	Intern, German Technical Cooperation (GTZ) Vientiane, Lao PDR
05/2008 – 07/2008	Intern, Federal Ministry for Economic Cooperation and Development (BMZ), Bonn, Germany
04/2007 – 04/2008	Student Research and Teaching Assistant, Univ. of Konstanz Konstanz, Germany
04/2005 – 09/2005	Student Teaching Assistant, Univ. of Konstanz Konstanz, Germany
03/2005	Intern, Federal Statistical Office of Germany Wiesbaden, Germany